SILICON CHIP

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ALL-NEW Programmable Electronic Ignition System

There's much more to GLASS than meets the eye!

Historical Radio Society of Australia

25 years restoring our radio history

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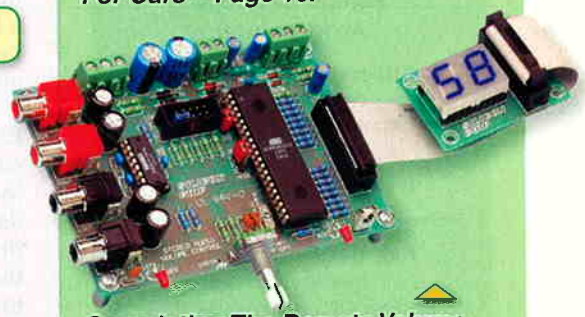

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Publisher's Letter

Earth Hour – a flawed concept

On the evening of March 31st 2007, Sydneysiders have been invited to turn off their lights for one hour, to demonstrate the deleterious effects of outdoor lighting on the night sky and to draw attention to energy conservation and reduction of greenhouse gases. The idea was put forward by the World Wildlife Fund. On the face of it, this is a great idea. As with just about every major city in the world, Sydney unnecessarily radiates vast amounts of heat and light up into the stratosphere every night.

Outdoor lighting is just the visible component of that waste and if we can do it on one night, even if only briefly, it might set a precedent which could be greatly extended. If building owners, businesses and ordinary residences can be persuaded to cut unnecessary outdoor lighting, we will cut energy wastage and also allow people to become a little more familiar with Sydney's spectacular bight skies. After all, the vast majority of the population would not be able to identify the Southern Cross or any of the far more prominent constellations.

However, while the idea of Earth Hour is good, the timing of it is just silly. Earth Hour is supposed to run from 7.30-8.30pm. But 7.30pm is not long after sunset on that evening so it will not be totally dark at that time. Worse still, the Moon rises at 5.41pm that evening and at that stage of the month, it is only two days away from full moon. So any effect of sky darkening by turning lights off that evening will be largely negated by a big bright moon. Perhaps the WWF and the other promoters of Earth Hour should have consulted with Sydney Observatory before putting the idea forward! The ideal time to have Earth Hour would have been to run from say 9.00-10.00pm (if indeed, it has to be confined to one hour) and to have it about time of New Moon. That way we could have a much better appreciation of the effect of cutting outdoor lighting.

In the meantime, if you want to get the effect yourself, just take a trip some 100km away from major cities and towns anywhere in Australia and then you can see a real dark sky, with all the beauty of the firmament fully revealed.

Longwall mining: an environmental disaster

In writing last month's editorial commenting on Ziggy Switkowski's report on nuclear power, I was conscious that there was very little on the environmental hazards of coal mining in the report. I thought that these should have been emphasised if Switkowski was really trying to promote nuclear power. In fact, I went looking for reports on the environmental impacts of open-cut coal mining but could find little that was really controversial.

However, just after I wrote that editorial, I was referred to the release of a new report on longwall coal mining in NSW, commissioned by the Total Environment Centre. Entitled, "Impacts of Longwall Coal Mining on the Environment in NSW", it sets out the appalling damage to rivers, creeks and the water table in general which occurs when longwall mining is performed. Furthermore, it details the damage to Sydney's water catchment at a time when the NSW government should have been doing everything possible to ensure Sydney's water supply.

But the blame cannot be all sheeted home to the mining companies. Their activities are permitted by the NSW government, at the same time as it has collected hundreds of millions of dollars in mining royalties. Frankly, it makes all the NSW government's announcements and policies relating to the State's water resources seem utterly hypocritical. You can download the complete report from **www.tec.org.au**

For those opposed to the burning of fossil fuels in power stations, to coal mining and the export of coal, it is damning evidence and another factor which is favourable to the future generation of nuclear power in Australia.

Leo Simpson

Powerful enough to detect interest.

Wade Barker
Navy Electronic Technician

When a piece of equipment fails it certainly is challenging, because there's a requirement to get it up and running in the shortest amount of time possible.

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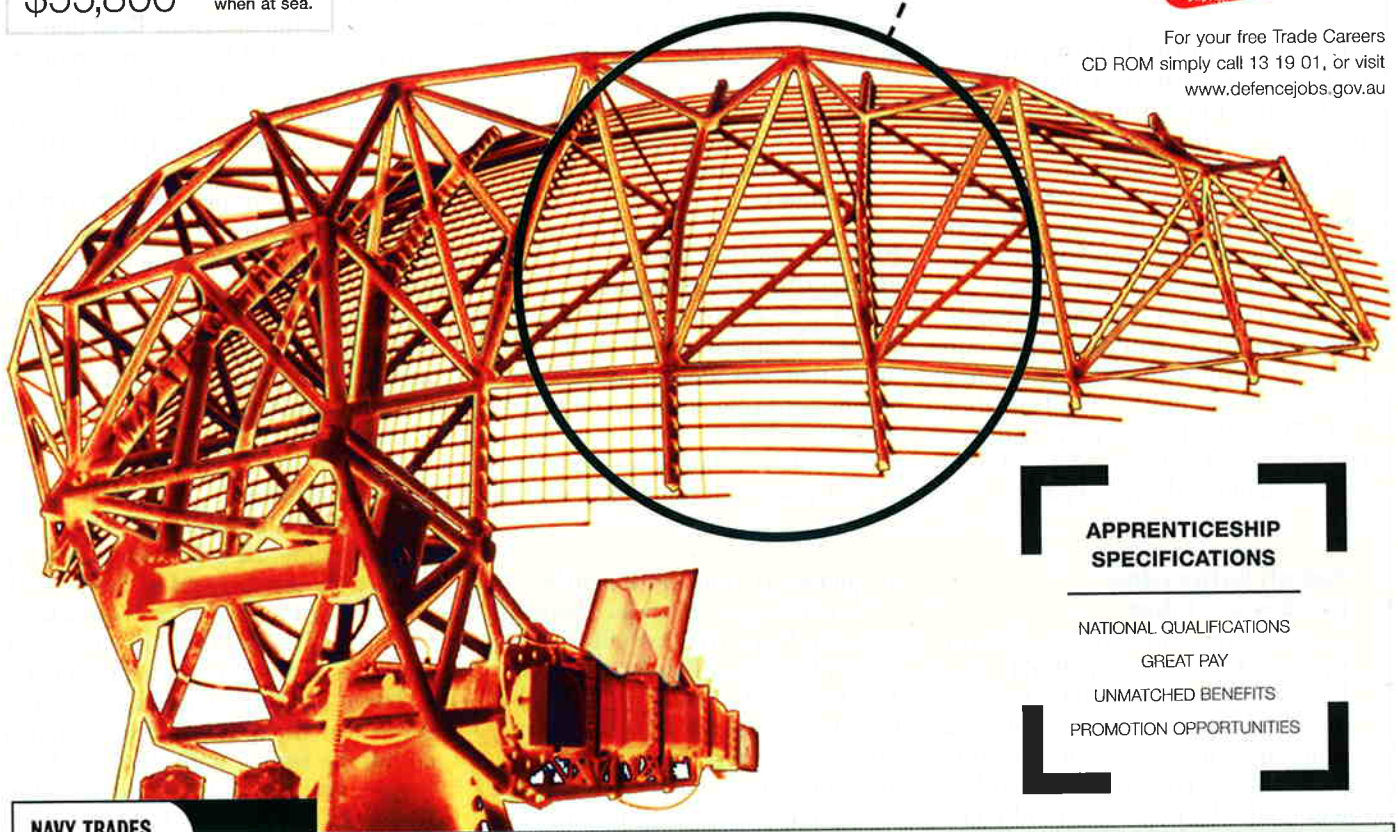

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MAILBAG

A simple approach to radiator fan switching

I read with interest your article on the automotive temperature switch in the January 2007 edition.

I recently upgraded a 1986 car to electric radiator fans to improve fuel economy and make the engine quieter. The way I got the fans to turn on and off was simple. I attached a circuit breaker (Altronics S-5595) to the radiator and used that to toggle a standard 12V automotive relay (Altronics S-4339). The circuit breakers come in different temperature set points and have built-in hysteresis.

Rob Clark,
via email.

Comments on the Intelligent Car Air-Conditioner Controller

I liked the Intelligent Car Air-Conditioner Controller project in the January 2007 issue. My suggestion is to add an extra function that switches on the air-conditioner every now and again during the winter months when the air-conditioner is not being used

I have been told that the air-conditioner should be switched on for short periods during winter to ensure that the rubber seals don't dry out and then leak. This extra feature may then save you the cost of replacing the seals and recharging the refrigerant gas.

Other than having to change the software to add this feature, the circuit would also need to be changed so that +12V power would be connected to the NO contacts of both Relay1 and Relay2. The NO contacts would need to be connected to the connection between the air-conditioner Fuse and the air-conditioner relay (or switch).

Roderick Wall,
via email.

Source for cartridge styli

I noted that Rodney Champness was having difficulty sourcing styli for the Philips RF5 Stereogram (Vintage Radio, January 2007 issue). He could try **www.garage-a-records.com**. They have just about every component for any turntable. I use them for the occasional turntable repair.

Pudney & Lee in Wellington, NZ, may also be able to help.

Ian McPherson,
via email.

Partner wanted for electronics development

I am a Mechanical Design Engineer and my business/hobby is the development of new ideas. I currently have one about to be commercialised and several on-going.

One idea under development involves programming a chip and displaying information on a screen for an exercise device. The concept has a novel twist and can be used on most exercise machines and I have been lent one by a local manufacturer/importer, who is interested in incorporating the idea into their machines.

My knowledge on this subject is limited, so I'm looking for a partner to develop the electronics, so that we can produce it. A brief search suggests the idea is novel (ie, patentable) and development would be on the basis of their part ownership and income from sales at a later stage.

If you live around the Tea Tree Gully area in South Australia, have the skills and this project interests you, please email me tony.rossiter@voice.net.au and I will outline the idea to you personally, under a confidentially agreement, so that you can decide.

Tony Rossiter,
via email.

Not all battery-less torches are fakes

Your correspondent Roger Forsey (SILICON CHIP, January 2007) must have been unlucky with his battery-less torches. I have bought three of them in various sizes but from auto parts shops. They have all worked well, with the larger one holding its charge and being able to shine its light at the push of the switch and with no further shaking.

In all of them, the "magnet" worked remarkably well, to the point where it would hold a teaspoon in mid-air despite the thickness of the torch case through which the magnetism had to work. Indeed, I cautioned my grandsons to keep the magnet away from credit cards!

A Google search under "battery-less torches" will reveal several battery torches, all modestly priced. The best that I have found, and a friend brought me four back from Hong Kong, is the compact, hold-in-the palm-of your-hand model which is operated by just squeezing the pistol grip on the underside. This model holds its charge well and is much easier to operate than those wind-the-handle things.

I gave up on the solar panel jobs; you can't recharge them if they are in the glove box or in the bedside table drawer.

John Richardson,
West Pymble, NSW.

Holden airship is actually a balloon

The article on the Holden/display airship in the December 2006 issue was very interesting. I have been a keen follower of lighter-than-air ships ever since I was a kid back during WW2.

There are three basic kinds. First, there are dirigibles, which have a complete frame with the gas bags inside and an outer skin over the frame. Zeppelins and the US Navy's Shenandoah-Class airships were of this kind. Then there are the blimps, which have a half-frame in the lower portion of the torpedo-shaped body. The most famous of these are the three Goodyear blimps.

Then there are balloons which have no frame at all. Examples are the Montgolfier Brothers' pioneering balloon, one of the very first to fly, then the hot air balloons of today and of course, the

Adjustable hysteresis for Battery Controller

I read the article in the December 2006 issue on the 12/24V Battery Isolator with enthusiasm. Over the years I have made up many of the original EA 1992 Low Voltage Cut-Out kits for myself and fellow campers. That kit is reliable and solves the problem of over-discharging the battery.

However, I have always been troubled by the fact that it draws a constant 70mA or so for as long as the relay is energised. With devices like refrigerators becoming more efficient both in terms of the current drawn and how much of each hour is taken up with the "on" duty cycle, that current drawn by the cut-out is becoming more significant, even if only psychologically so. As you correctly observe, every microamp is indeed precious.

This new controller could be just the bee's knees as a superior replacement, not only because of its negligible current drain but also its robust current capacity. However, it appears that, in the low-voltage protection mode, it has almost no hysteresis. If set to drop out at say, 10.5V, it would cut back in again at 11.1V.

Even with a modest load of 2A or 3A, the device would cut out at 10.5V and the battery voltage would almost immediately drift up to considerably more than the 11.1V cut-in voltage. It would cycle thus, with possible bad effects on the fridge etc, until the battery was finally drained enough to not drift up much. This is a problem we experience with the standard cutouts found on some 12V refrigerators over the years.

The EA kit has an adjustable hysteresis, so you can have the controller cutting out at 10.5V to 11.5V and the cut-in happening at say 12.9V. This is an effective solution. Can we add this capability to the new controller?

John Keitley,
via email.

Comment: we referred this question to the designer, Branko Justic, at Oatley Electronics. His reply is as follows.

The hysteresis of the voltage sensing comparator of the L4949 IC is around 8%, which corresponds to 0.8V at a battery voltage of 10.5V. As pointed out, this may not be sufficient in practice.

A simple way to increase the hysteresis would be to add a series resistor and diode combination between the input pin of the comparator (2) and the open collector output pin (7).

With this in place, when the battery voltage is high the open-collector transistor is off and the voltage is pulled high (+5V). The additional diode is reverse-biased so this network would not have any effect on the voltage at the voltage-sensing comparator.

However, when the battery voltage falls below the lower set limit, the open-collector transistor is turned on and the series resistor/diode combination would add extra loading between the comparator input pin and ground. This means that the battery voltage would have to rise to a higher figure before cut-in, amounting to increased hysteresis.

With a series 1N4148 diode and 43kΩ resistor combination connected between pins 2 & 7 of the L4949 IC and with the cut-out voltage set to 10.5V, the cut-in voltage was 12.9V. We will modify our PC boards to make provision for these components and include a note with our kits.

Branko Justic,
Oatley Electronics Pty Ltd.

famous barrage balloons which flew over cities in wartime. These barrage balloons were large and tethered by strong cables and were there to interfere with low flying aircraft.

Contrary to the statement in the article indicating it was either a dirigible or a blimp, the Holden airship is actually a balloon. It has no internal structure or frame and the gondola is attached in the standard balloon manner, suspended by a set of cables from the gas bag. The main difference between a barrage balloon and this air-

Atmel's AVR, from JED in Australia

JED has designed a range of single board computers and modules as a way of using the AVR without SMT board design

The **AVR570** module (above) is a way of using an ATmega128 CPU on a user base board without having to lay out the intricate, surface-mounted surrounds of the CPU, and then having to manufacture your board on an SMT robot line. Instead you simply layout a square for four 0.1" spaced socket strips and plug in our pre-tested module. The module has the crystal, resetter, AVR-ISP programming header (and an optional JTAG ICE pad), as well as programming signal switching. For a little extra, we load a DS1305 RTC, crystal and Li battery underneath, which uses SPI and port G.
See JED's www site for a datasheet.

AVR573 Single Board Computer

This board uses the AVR570 module and adds 20 An./Dig. inputs, 12 FET outputs, LCD/Kbd, 2xRS232, 1xRS485, 1-Wire, power reg. etc. **See www.jedmicro.com.au/avr.htm**

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Mailbag: continued

3-phase motors have excellent torque

I've worked extensively with the application of 3-phase induction motors in industry and I don't agree with the comments of correspondent Jeff Jones (December 2006 Mailbag) who says they have poor start torques. Induction motors started direct on line (DOL) have excellent start torque characteristics – typically locked rotor start torques are more than twice the motor full load torque. This start torque remains reasonably constant until the motor approaches its running speed, where the torque delivered by the motor reduces to match the load.

I agree that reduced voltage start methods decimate the starting torque (start torque varies as the square of the voltage).

Even with DOL starting, high-inertia start loads can trip you up. A classic example for us was the application of centrifugal blowers. They often have a small aerodynamic load due to low air volumes but a high mechanical inertial load due to a large diameter but narrow rotor.

Motor size is traditionally established from the aerodynamic load and this means the run up period to full speed can be long – and with a typical start current draw of 5-7 times the full load current, they had a tendency to trip their thermal overloads. This was usually solved by using electronic overloads with an adjustable run up time.

I like your editorials which take an honest and straightforward look at the state of things. There is an eye on waste and sustainability which is good. So why the extensive feature on the airship in the December issue? It may be technically interesting but is an unnecessary and an expensive waste of resources for no real purpose other than to serve as a floating billboard.

If you believe we need more invasive exposure to advertisers then I've misjudged you. I frankly don't see any point in its existence. You lead the way in asking why car manufacturers now add frills and not enhanced performance and economy to their cars and yet in the same breath laud this thing.

I read your article on cheap battery drills and like a man enlightened I rushed out to purchase new batteries for my favourite (and ailing) drill. Now repacked, I look to the smart charger and well . . . phew! It's pretty clever but isn't it really applying a hammer to crack a nut?

Why not just charge the drill at the trickle current and leave it at that? OK, it takes 20-30 hours to fully charge but if you can leave it on all the time then it is likely to be fully charged and ready when you need it. So it goes flat part-way through that job? If you are like me, I wouldn't wait even three hours for a drill to recharge, I'd curse, go to the garage and drag out a lead and power drill and finish the job.

OK, that wouldn't suit a tradesman but they wouldn't use these cheap drills anyway. I'm talking of the home handyman.

The extensive kit development you do for cars is fascinating but the thought of dissecting my car's dash facia to fit any of them is scary.

Andrew Buchanan,
via email.

Comment: we agree that we don't need any more advertising but we thought the technical story of the airship was of interest.

We realise many people would be reluctant to break into their car's wiring but we believe that we should show what is possible.

ship is the rigid tail fins with control surfaces.

I was quite surprised at the statement that the gondola was built on a steel frame, as this would be nearly twice as heavy, for the same strength, as aluminium/magnesium alloy framing. I don't know of any other lighter-than-air vessel with steel in the structure except where its use is unavoidable; eg, as support for the engines. And in many designs this too is made from forged aluminium alloy.

The Montgolfier balloon was lifted by methane, which is only one third as dense as air (but easily available in those days). Helium is 1/10th and hydrogen 1/20th as dense as air.

The only suitable lifting gas for dirigible airships is hydrogen. The US Navy's attempts to use helium in their dirigibles saw all five quickly lost in storms at sea – all of them came down with the loss of all life. Helium is simply too dense to lift that kind of weight.

Blimps have a limited weight-carrying capacity, even with only half the frame of a dirigible, due to the limitation of using the higher density gas, helium.

Pure hydrogen is perfectly safe; it cannot explode unless contaminated with oxygen (as will all flammable gases) and will just burn if there is a fire. No Zeppelin other than the famous Hindenberg ever crashed or was lost.

The Zeppelins were truly huge. Their scale was unimaginable – they carried many fully furnished cabins, a ballroom, dining room, galleys and nearly everything an ocean-going luxury cruise ship would have. It was – even built of aluminium – a massive amount of weight but was lifted with lots of capacity remaining by hydrogen-filled gas bags which at cruising altitude occupied less than half the interior of the ship.

Too bad that since the Hindenberg's destruction, hydrogen is not preferred for lifting airships, even though it is not really a serious danger or problem – in fact it is easier to contain than helium, the "escape artist" of the gases.

Bear Stanley,
Atherton, Qld.

Audio tones can cause clocks to gain time

With respect to the letter in "Ask Silicon Chip" in the December 2006 issue, the writer is quite correct in that AFIC (Audio Frequency Injection Control) tones which are used for off-peak, street light and tariff switching can affect digital clocks.

This usually happens when the tones exceed 20V and the clocks race

due to multiple zero crossings during the tone burst. This can be from minutes to hours, depending on the level. The injected level is usually set to between 3V and 10V superimposed on 240VAC. The signal rises, usually due to the area in question being supplied by a feeder that consists of a long length of overhead cable with an underground subdivision at the end. This can create a resonant circuit at the control frequency which then acts as a voltage doubler.

John O'Brien,
via email.

Remote Telltale for Garage Doors

I have a comment regarding the microswitch arrangement for the top & bottom limits on the door track shown on the inset photo on page 59 of the Remote Telltale for Garage Doors in the January 2007 issue. The arrangement shown assumes that the door is going to stop in the same position each time it reaches its upper and lower limits, which is not always the case, particularly if the door is manually raised and lowered.

A better arrangement would be to orientate each switch at 90° to the inset shown whereby the switch activator points towards the door and a sprung follower is attached to the door to activate the microswitch. An even better arrangement would be to install a magnet and reed switch which requires no mechanical contact.

If your house has a security system that protects the garage doors, the door magnet could activate the additional reed switches when the door reaches its upper or lower position.

Mal Land, via email.

Comment: we did not envisage that this project would be built for a door that was manually operated. However, your comments on manually-operated doors are quite valid.

RME equipment search

I would like to hear from anyone who used to work for a company called RME that used to be in Sydney and made broadcast equipment for radio stations.

Specifically, I am looking for the plans/PC board layouts, or even original boards, for the 451M1 LED Level Monitor they used to make. Ultimately, if someone has a complete unit, I would be most interested in buying it but

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Mailbag: continued

Electrical licensing is still a bureaucratic mess

I'm writing in regard to the electrical wiring license debate which will very soon raise its head once again. As a frequent magazine buyer, I read many of the responses a few years ago from SILICON CHIP readers and can only agree with the readers and look in disbelief at the unreasonable electrical licensing rules, especially those in Queensland.

As you may be aware, 2007 could be scheduled for a review of the Electrical Safety Act in Queensland which was last written in 2002, since it has been five years since the last publication.

I'm writing to give an indication to you and the other readers as to the difficulty in becoming a licensed electrical worker in Queensland from my own experience.

Throughout my university studies, completing a Bachelor of Electrical & Computer Engineering, I was working part-time at a small TV radio repair shop as an electronics technician repairing TVs, consumer electronics and audio-visual equipment for around 20 hours per week. This work was supervised by an experienced and restricted licensed technician and has continued on a part-time basis despite having a full-time engineering position since completion of my studies.

When I first began my engineering position I was required to confirm my ability to perform some wiring. My position does require me to construct prototypes and test electrical components for use in designs which involves a disconnect/reconnect licence.

Prior to approaching the ESO in Queensland about a licence, I had read the current Safety Act and noticed a clause which is still current, stating that a person does not require an electrical license for the performance and supervision of electrical work as part of practising the person's profession as an electrical engineer.

I contacted the ESO to confirm my understanding of the clause. I obtained many varying responses which did not give me any confidence in my understanding of the clause before I eventually spoke to the head of licensing at the time who I explained my position and work to and was informed that the work I was doing is covered by the clause although the clause would not cover my second job as a technician.

This led me to apply to obtain a restricted electrical license in order to continue the technician work. Applying for a license requires completion of forms which require details, evidence of a trade or calling requiring an electrical license,

board layouts would be the next best. Please contact me at **happydayradio@hotmail.com.**

S. Williamson,
via email.

Safer method for discharging microwave oven capacitors

I read with some awe the description of how to discharge a high-voltage capacitor in the December 2006 issue, on page 94. A dead short on a fully charged capacitor is foolish, very frightening and almost as dangerous as leaving it fully charged. The correct way to deal with it is much less spectacular: a resistor of about 1kΩ, well insulated (eg, contained within a plastic box), connect one side solidly to ground (as one side of the capacitor is usually grounded, through the transformer secondary winding and often a high-voltage fuse), and connect the other side to each side of the capacitor in turn.

Use something like a high voltage screwdriver as pictured in the article, and tape a good quality multimeter probe to it. There should be a small arc if there is any charge in the capacitor.

Be aware that if the high voltage fuse has blown, you will need to connect directly across the capacitor but try

JP-signed evidence of CPR qualifications and paying the prescribed fee for processing.

Several weeks passed without a response before eventually getting a letter stating that an electrical engineer is not a trade or calling that requires an electrical license and that my application was rejected. I then obtained a number of letters from my employer as evidence of my requirement to perform electrical work and resubmitted my application.

Many weeks passed before getting another lot of paperwork from the ESO containing a training permit stating that I would have to complete at a relevant TAFE college a number of courses and sign-off from an electrical worker of my competence to perform the required electrical work. My electrical engineering degree, according to the ESO, means nothing for the purpose of obtaining a license.

I eventually found a TAFE college that permitted me to sit for the relevant exams and practical competency tests, saving me around $1600 normally required in fees to enrol in the appropriate courses. After eventually having completed all examinations for the license, a completion statement of my competence in electrical wiring was sent to the ESO for me to obtain the license. The ESO managed to lose the relevant documentation several times, delaying the process by a further two months before I finally obtained a licence.

As you may appreciate, the process for obtaining a licence is extremely difficult and frustrating. I believe that electronics technicians should be issued with the license as part of their trade and that electrical engineers should have a complete unrestricted electrical work licence.

Don't get me wrong, I do not believe some electrical engineers after completion of their studies are competent at performing wiring but . . . they should be. Punishment should be on unsafe wiring rather than based on relevant licensing.

The ESO appear to have the rules in place for ensuring business and economic growth for electricians and have no regard for electrical engineers, electronic diploma graduates, technicians and DIY hobbyists that simply want to construct electronic circuits for their own use.

The unrealistic stand the ESO has taken on licensing and the unbelievable difficulty in obtaining a license is unacceptable. I very much hope that some serious changes are made to the Electrical Safety Act before the next amendment is published.

Name and address supplied but withheld at the writer's request.

Comment: the Queensland bureaucracy continues to amaze with their ongoing stupidity with regard to electrical licensing and safety. The other states are not much better.

the ground method first. This is MUCH safer and then you can go directly across the capacitor. Refer to the WES components Microwave Oven Servicing Manual for further information. There are 2½ pages of safety notes, quite a few of which are applicable to those recycling the bits.

I service electric fence energisers and need to discharge the dump capacitors, typically 30µF to 120µF charged up to 900V through a mains doubler or tripler circuit. I use a simple pair of multimeter probes with eight 560Ω 0.5W resistors in series within the probe bodies (four in each). The probe tips are long enough that I can short them together after about five seconds, just to make sure the capacitor is discharged. There is enough energy in these capacitors to destroy the tip of a screwdriver.

With regard to microwave transformers, it is easy to cut off the existing secondary (with a hacksaw and cold chisel combination) and wind a new low voltage secondary on it. OK, maybe it will not be pretty or 99% efficient but the primary winding is generally well protected and it is a big impressive-looking heap of iron.

David Walters,
David Walters Electronic Services,
Dubbo, NSW.

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PCs – Taking Gl
the Simple Wind

Silicon. One of the Earth's most prolific substances, yet so important in our 21st century lives – from computers to disc technology – and glass.

Far from simply being a see-through flat sheet, these days glass is often shaped and 'value-added' to suit many applications.

You would know glass can be produced to block or reduce heat, glare or noise (or a combination of all three). It can be tinted, it can be one-way, it can be patterned. But these days, thanks to the humble PC, glass can be so much more.

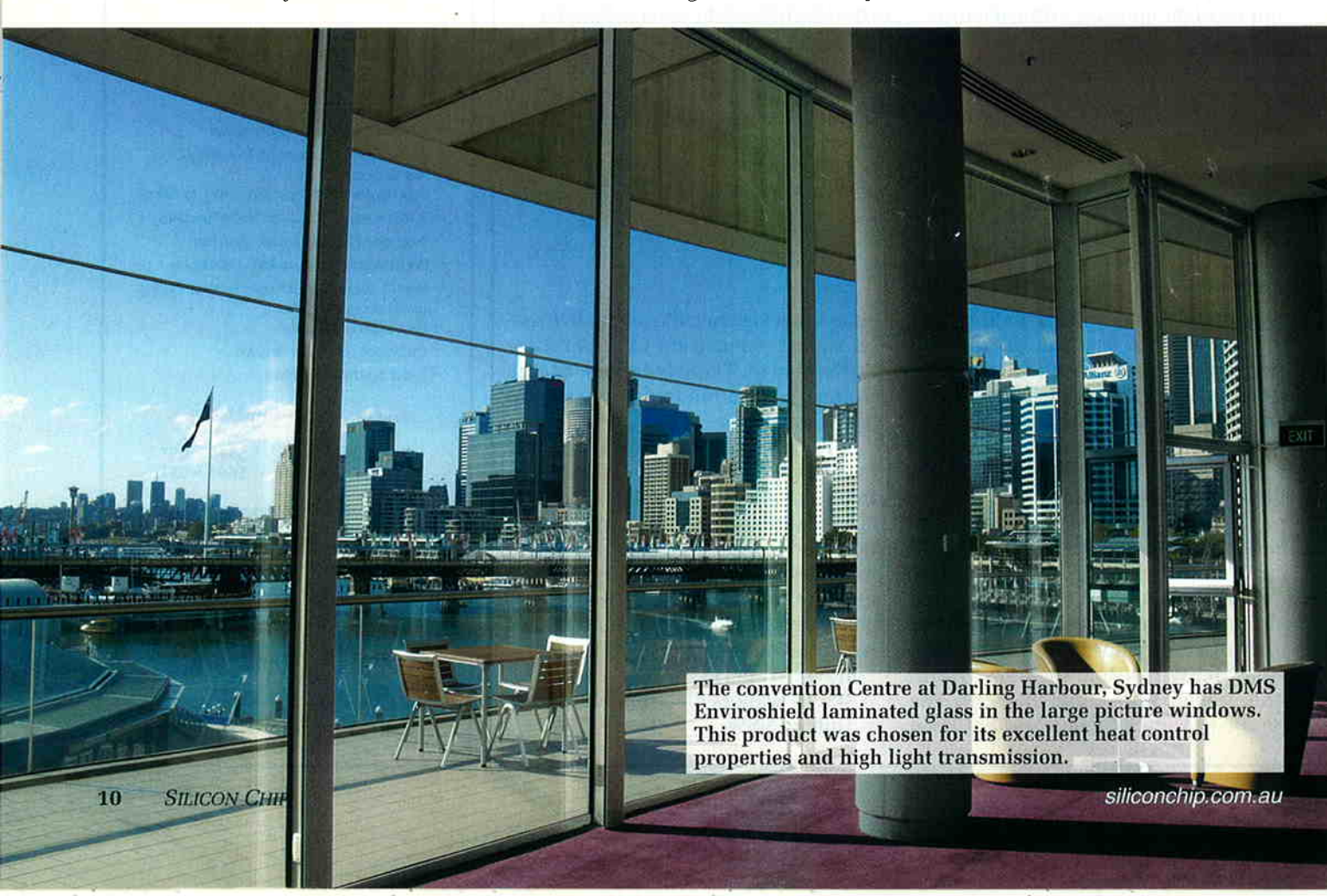
Much of the glass enhancement would be infinitely more labor-intensive, expensive and complex – in fact, may not even be possible to produce – without computers.

Here we look at a major glass supplier's use of computers to help manufacture some unique products.

DMS Glass in Melbourne is one of the largest glass enhancement manufacturers, producing products that we often see but usually don't appreciate the technology employed to make it. Like not being able to see the wood for the trees, glass is traditionally something you look through, not at.

DMS Glass's vast plant has made glass for sites like the Olympic Games facilities at Homebush, Hong Kong Airport, Crown Casino, Rialto tower, Melbourne Entertainment Centre, Melbourne Museum and Flemington Racecourse, to name a few.

Just some of the products they make include laminated (toughened) glass, ballistic (bullet-resistant) glass and Digiglass, a laminated, printed glass invented in Australia.



The convention Centre at Darling Harbour, Sydney has DMS Enviroshield laminated glass in the large picture windows. This product was chosen for its excellent heat control properties and high light transmission.

ass Way Beyond low Pane!

By Kevin Poulter

Each manufacturing step (and indeed the whole plant) is controlled by 'mid-weight' PCs or higher-power specialty computers. This results in some huge machinery controlled by modest size computers.

Toughened glass

Toughened glass is manufactured by exposing ordinary annealed glass to extremely high temperatures in an oven prior to entering a chilling chamber.

This process induces stresses within the glass that enhance the panel's strength by approximately five times. A PC controls the speed, time and temperature of the glass when it is in the various phases of the toughening plant.

Laminated glass

Laminated glass is manufactured by inserting a Poly Vinyl Butyral (PVB) interlayer between two sheets of glass, with the clean-room environment ensuring blemish-free glass.

The assembled glass is transferred to an oven and roller press (to force out any trapped air) via an automated roller system. Computer sensors detect the glass movement, with a PC controlling the production-line flow.

The laminated glass is exposed to temperature and pressure in an autoclave to finalise the bond. When laminated glass has more than two glass panes, a PVB interlayer is placed between each glass layer.

Stopping a bullet

Ballistic glass is a laminated glass with multiple layers of glass and interlayers, designed to remain intact after attack by bullet, hammer, axe or similar weapon. This glass is also used for prison windows.

Some ballistic glass is designed to maintain integrity against blast. It is manufactured in accordance with Australian/New Zealand Standards AS/NZS 2343.

The thickness and quantity varies depending on the ballistic threat level. No one ballistic glass is suitable to meet all levels of ballistic threat and therefore a ballistic glass designed to protect against a 9mm pistol threat is considerably thinner than glass designed to withstand a .357 Magnum.

Part of the AS/NZS 2343 compliance requirements are that the sample glass panels are shot three times within a set spacing with no 'spall' fragments penetrating a paper backing.

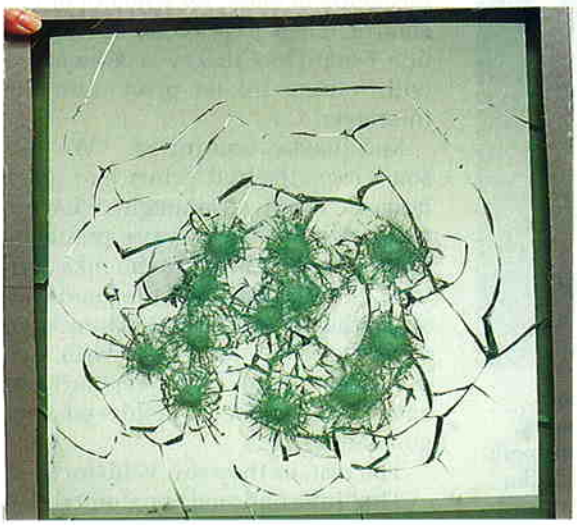
I attended a number of ballistic glass tests, in a discrete underground firing-range in Melbourne's suburbs. Few neighbours would know that below a small factory, firearms are used for tests or training most of the time.

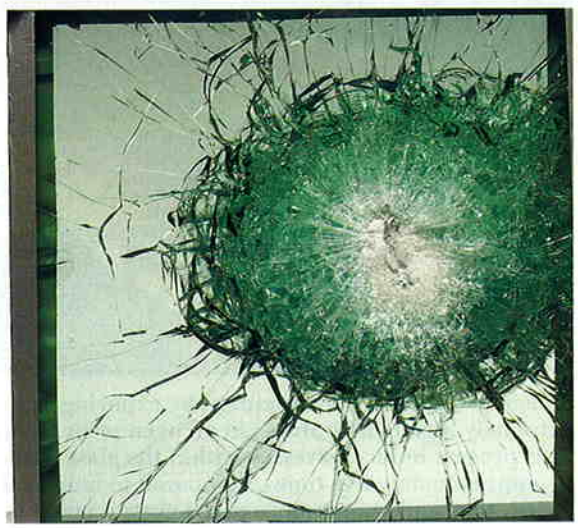
The glass resisted the best efforts with all kinds of firearms, with bullets and axes not managing to open a hole. There was plenty of cracking but there was no way that anyone could enter a building protected by this glass – even when the number of shots exceeded test parameters.

Blast-resistant glass is far more challenging to develop, due to the uncertainty of the size and position of the bomb, plus the associated forces. Extensive, detailed tests are carried out to design a glass capable of withstanding the worst case example.

Digiglass

DMS's own printed and laminated Digiglass is an amazing product. The industry historically has never been very inventive at decorating with glass but this medium has certainly opened





This is the result of a high-powered weapon shot. The glass is marked, but still intact. Ballistic glass is laminated glass or multiple layers of glass and interlayers that vary in thickness and quantity depending on the ballistic threat level.

Very little glass is either cut or processed by hand these days. The human operator has been replaced by PC consoles in nearly all aspects of order entry, glass cutting, edge-working, drilling, laminating, CNC precision notching, toughening and water jet cutting. It's staggering to see the impact of computers within the DMS 60,000 square metre factory and the glass industry in general, in the last ten years.

The internationally patented Digiglass process digitally prints images directly onto a specially formulated PVB interlayer with compatible inks which are resilient to UV fading The digitally printed interlayer is then laminated between glass panels, encapsulating the image between glass, protecting the image for the life of the panel.

up whole new areas – memorials, mausoleums, decorating skylights, features in walls or entire cladding of buildings.

DMS glass international Marketing Manager, Gerard McCluskey and inventor of Digiglass, said "We are continually taking the product into new areas, where glass has never been before".

"Our role is creating an understanding of what its capabilities are. Historically glass has always been perceived as a product that keeps out the wind and rain. Now with the latest techniques and manufacturing processes, it can achieve a lot more."

Five years ago, screen-printing or adhesive films were used to place images on glass. The adhesive method was high maintenance and deteriorated quickly.

The solution was simple in concept, if not in the development. For years, DMS has added a film lamination to the centre of glass, for strength or UV control. Then in a stroke of inspiration, Gerard McCluskey experimented with adding ink-jet print onto the interlayer.

McCluskey continued: "We ran some experimental prints and got a fantastic result, so I thought 'what are we onto here!' There were problems with adhesion, because the inks contaminated the surface of the interlayer, so another uncontaminated interlayer was placed on top. Now with two uncontaminated interlayer surfaces against the glass, we achieved very good adhesion."

The rest, as they say, is history.

The internationally-patented Di-

Toughened glass is manufactured by exposing ordinary annealed glass to extremely high temperatures in an oven prior to entering a chilling chamber. This process induces stresses within the glass that enhance the panel's strength by approximately five times, compared to annealed glass. The PC controls the speed, time and temperature of the glass when it is in the toughening plant.

Glass orders from perhaps many customers are loaded on a PC for 'optimisation', for the lowest-waste layouts. This is a vital step in efficiency and economy. The computed data is fed to the cutting table at right.

A diamond-tipped wheel zips around the glass at great speed, cutting the shapes. A sheet of glass is easily moved on the table, as air is fed through a pattern of holes, making the glass 'float' easily on command. When in the correct position, the airflow is reversed, with the suction holding the glass firmly in place. Some tables rise to vertical, vertical storage of the glass until ready for shipment.

giglass process consists of digitally printing images directly onto a specially formulated PVB interlayer with compatible inks, resistant to UV fading when glazed externally. The printed interlayer, in high-resolution full colour, is then laminated between Grade-A safety glass panels, encapsulating the image and protecting it for the life of the panel. This technology is now sold around the world.

McCluskey is excited with the Digiglass versatility. "The beauty of our product is we can produce a panel today and replicate it in 10 years time for whatever reason. If it needs to be replaced we can make a copy, or even change the colours or tonings to match it to the latest surroundings."

DMS established worldwide patents but not possessing the international clout to rebuff copycat interlopers, engaged DuPont to market the product outside Australia and New Zealand.

Now buildings and features such as the Memorial to the Canberra Bush Fires and many in USA feature Digiglass.

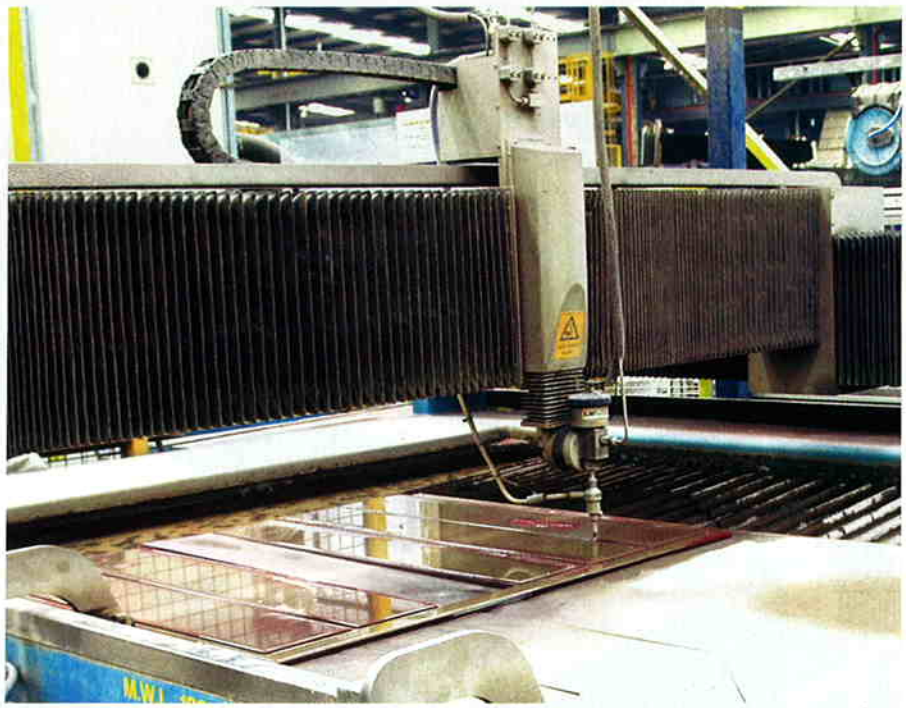
How it's done

A graphic artist makes the image graphic file on a PC, then the file is loaded into a DMS PC for formatting. Graphic file sizes can be as large as 1GB. Once formatted for production, the data is forwarded by cable to a very large ink-jet printer deep in the factory. Even the inkwells make a home printer seem tiny!

The image or pattern is printed onto the interlayer film, in a dust-free environment. Specially developed proprietary inks and interlayers are used in combination to offer the ideal adhesion, resolution, and dimensional properties needed.

The printed film is then taken to the laminating-room, a clean room with a multi-million-dollar computer-controlled laminator.

Being PC generated, last-minute



Some glass is cut by a high-pressure jet of water. Water jet cutting of glass is a relatively new innovation and is extremely efficient when cutting multi-ply glass laminates or complex shapes. Again, the process is controlled by a PC.

changes and previews, such as four different color versions of the same image for comparison, are no problem.

Applications are as varied as the imagination – even bus shelters, where Digiglass creates a feeling of openness and cleanliness, while still offering people a good view of approaching buses or people.

Even vandalism seems to have been reduced – as soon as Digiglass started putting images within glass, less panels needed replacement. Perhaps it was because the glass was now telling a story, it had a theme or had a pictorial image and was no longer something simple to be destroyed.

Beauty and brains.

Digiglass is visually dramatic and beautiful, plus just as strong and practical as any glass. The product meets AS/NZ 2208 Grade A Safety Glass standards.

A very successful but initially unanticipated application is Digiglass images in laminated glass memorial products. The product has been recognised by DuPont in the Australian and New Zealand Innovation Awards, as a finalist in the Construction and Architecture category.

The walls in the lift at the new Mercedes Benz Melbourne showroom are Digiglass, displaying their notable sports cars. Located in South Melbourne, the showroom is predominately a steel and glass structure, designed to convey the sense of quality associated with the automobiles on display.

The outside of the building is DMS Enviroshield Sunergy Clear Heat Strengthened Laminate. The 12.76 mm laminated glass, which incorporates XIR 72-74 film by Southwall Technologies, created a neutral colour, energy-efficient product with exceptional solar and thermal control properties.

The glass has an exceptionally high light-transmission of 72% to maximise daylight, while offering increased comfort and superior reduction in solar heat gain (0.47 solar heat gain coefficient) and minimising outside noise.

Glass is a very unforgiving product. It is unlike any other building product. It's brittle but it's probably the most hard-working and long-term building product; one that needs very little maintenance. When processed for strength, it's suitable for stairs and walkways, or even for armored vehicles.

Computing power

Until the 1980s all glass processing, including cutting and edging, was done by hand. The skills of the tradesmen had to be at a very high level but now, with advances in computers and electronics, hi-tech methods of cutting and edging glass are employed.

One area where PCs now save time and money is optimisation. For best efficiency and economy, the 'jigsaw' shapes of a number of orders are placed into a computer program and the best use of the available sheet-glass area is plotted.

This enables the biggest sheets of glass to be cut into shapes for two, five or even ten different customers.

The computer optimising application can reduce the off-cut factor down to a minimum, with a waste factor of 5% regularly achieved.

The fully automatic glass lamination process. In the white room environment, which ensures cleanliness and a blemish-free glass finish, glass is assembled either side of the PVB interlayer. This is then transferred to an oven and press via an automated roller system, controlled by computer sensors detecting the glass movement.

Most often the large sheets of glass are cut into customer-ordered oblongs but any conceivable irregular shape can also be cut. To order irregular shapes (for example a peanut-shape tabletop) designers supply a precise template in wood.

The template is photographed, then goes into a CAD system. If out of square or irregular, shapes and dimensions can't be taken, a probe is used to touch multiple points, automatically sending data back to the computer and rapidly creating the overall panel dimensions.

The optimised and shape data is fed into the cutting and/or hole-cutting machines' computers.

Cutting and hole drilling is achieved either on a rapid diamond-cutter, the immensely powerful water-jet cutter or hole drill. With the latter, holes are drilled from both sides at the same time, to avoid burrs and chipping (known as 'shelling').

Precision drilling of glass is vital for accurate installation of fittings such as handles, hinges, etc. All processing of glass must be completed prior to the toughening process as once toughened it is considered a finished product. These computer-driven drilling, notching and routing machines offer pinpoint accuracy.

The recently-finished Mercedes Melbourne Car Showroom chose Digiglass to depict vehicles of various eras in the showroom lift. The Digiglass mural only requires routine cleaning, as the image is protected within the laminated glass.

With the table-type glasscutter, a single operator can glide a huge sheet of glass into position with ease, thanks to a cushion of air.

A multitude of holes, all about the size of drinking-straws, are fed air under the glass. This enables the operator to 'glide' the heavy glass into position.

Then the air is evacuated, holding the glass firmly and precisely in place.

While their hole-cutting CNC machines make a complete cut, the shape 'cutting' tables only score the outline, so most glass-cutting tables now have automatic breakout capabilities. An air-driven foot pump activates bars that rise up underneath the scored glass, to push the cuts apart. Some tables rise to vertical, allowing glass to be stored vertically, until ready for shipment.

Tracking the glass

Large manufacturing plants need to track orders to ensure timely completion, schedule production, optimising and capacity planning. DMS glass has introduced a barcode system, so each step is 'read' on completion and automatically recorded into the server's files.

Heat treatment will dislodge the barcode, so at a number of stages, the stickers are removed and subsequently replaced with new stickers after treatment.

The advantages of barcoding are many, such as quick reordering a part if it does not pass inspection and maximis-ing the output and efficiency of production machinery.

Computers are integral right through the manufacturing process and even include DMS glass delivery. As the trucks make their way to the clients, they are monitored on screen by a Global Positioning System! SC

By JOHN CLARKE

Programmable Ig System For Cars;

Want to program the ignition timing on your car? Now you can, with this completely new design. It can be used in older cars which presently do not have electronic ignition or used as an "interceptor" for cars with engine management systems.

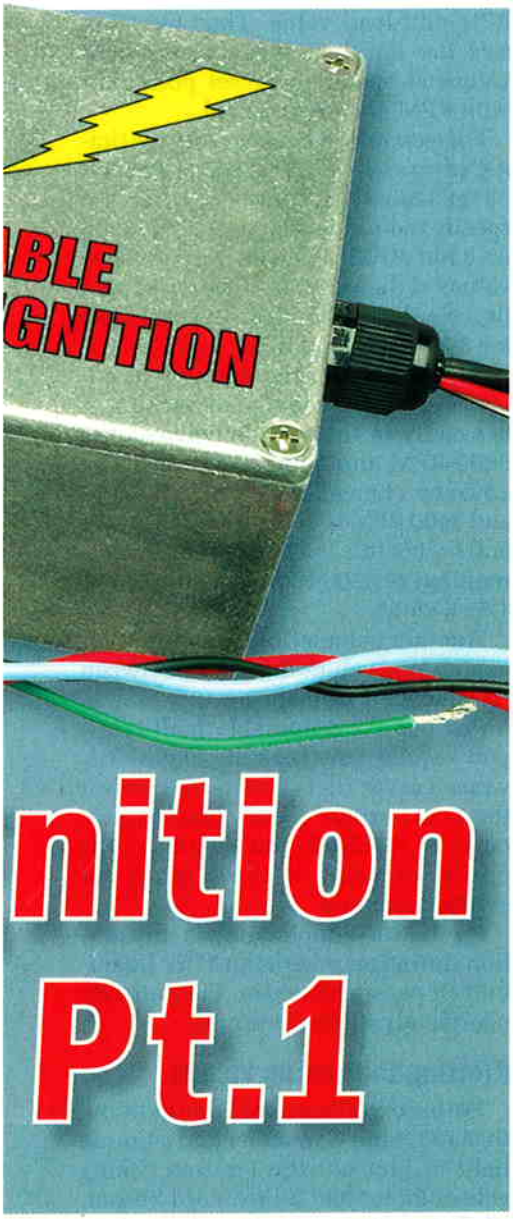
OUR PREVIOUS Programmable Ignition was originally published in March 1996 and proved to be a very popular project with readers. This was subsequently updated as the Programmable Ignition Timing (PIT) Module in the June and July 1999 issues of SILICON CHIP.

The updated PIT module included a basic 2-step advance curve and a 1-step vacuum advance that changed the timing according to engine load. In operation, it was used to control the High Energy Ignition design from the June 1998 issue.

This latest Programmable Ignition from SILICON CHIP is far more advanced in features and its ability to produce an accurate advance curve. It is also a complete stand-alone ignition system that is triggered by an engine position sensor and then drives the ignition coil. It can be triggered from one of many sensors in a distributor, including points, reluctor, Hall effect, optical trigger and the 5V signal from the car's Engine Control Unit (ECU).

In order to measure engine load, the Programmable Ignition can use a Sensym absolute pressure sensor. In fact, provision has been made to mount this sensor directly on the PC board, the sensor then being connected to the engine manifold via plastic tubing.

Alternatively, you can connect the ignition circuit to an existing manifold pressure sensor if present. This is commonly called a Manifold Absolute



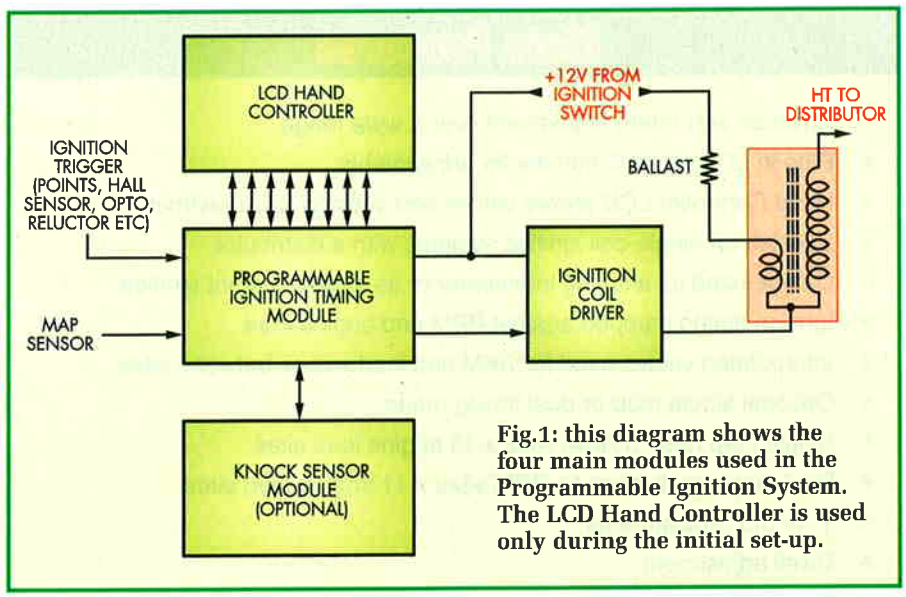


Fig.1: this diagram shows the four main modules used in the Programmable Ignition System. The LCD Hand Controller is used only during the initial set-up.

Pressure (or MAP) sensor and is found on many cars these days. You could also use a secondhand MAP sensor from an auto wrecker.

Changing the timing

A fully effective ignition system needs to increase the timing advance with increasing RPM and to alter the timing according to engine load – all with a fair degree of precision. Additionally, some means to detect detonation (knock) and retard the timing would be an advantage. In this way, the ignition can be advanced further than would otherwise be possible without knock sensing.

This latest SILICON CHIP Programmable Ignition incorporates all these features. What's more, there is an option to select between two separate ignition-timing curves using a switch. This option is ideal if you are running both petrol and gas, where a different timing curve is required for each type of fuel.

Fig.1 shows the complete system. It comes in four modules: an LCD Hand Controller, a Programmable Ignition Timing (PIT) module, an Ignition Coil Driver module and a Knock Sensor module. The first three modules are mandatory, while the fourth, the Knock Sensor module, is optional.

The heart of the system is the Programmable Ignition Timing module, based on a PIC16F88-E/P micro. It is programmed by the LCD Hand Controller and it delivers a signal to the Ignition Coil Driver. The latter, as its name suggests, then drives the ignition coil.

LCD Hand Controller

The LCD Hand Controller is similar to the one featured in our book "Performance Electronics for Cars". It was originally designed for setting up the Digital Pulse Adjuster, Digital Fuel Adjuster and Independent Boost Controller projects featured in that book.

The Hand Controller is used during the initial setting-up procedure. It plugs into the main unit and can be used while the engine is either running or stopped. It is then normally disconnected from the main unit after all adjustments have been made.

Using the Hand Controller, you can set all the initial parameters and also program the ignition advance/retard curve. Several pushbutton switches on the Hand Controller enable these changes to be made.

Knock sensor

The optional Knock Sensor module enables "pinging" to be sensed and the ignition timing retarded for a brief period. In brief, engine pinging is monitored by the Knock Sensor and the Programmable Ignition Timing (PIT) module for the first 6ms after each spark. However, at high RPM, there is less than 6ms between each firing and so knock signal monitoring is done between each spark and the start of the next coil dwell period.

When engine knock is detected, the timing is retarded for the next 10 sparks. The amount of retardation varies according to the severity of the knock signal. More details on this are given in the specifications.

Different uses

The Programmable Ignition can be used either as an interceptor or for fully mapped ignition timing. In the interceptor role, it can vary the existing ignition timing by advancing or retarding it from its current value – ie, it can be used to alter the timing signals from the car's ECU.

Alternatively, when used to completely replace the existing ignition timing, you will need to obtain the advance/retard curve for your vehicle so that the entire timing curve can be produced by the Programmable Ignition. For some vehicles, you may

Main Features

- Advance and retard adjustment over a wide range
- Plug-in LCD Hand Controller for adjustments
- Hand Controller LCD shows values and settings for adjustment
- Suitable for single-coil ignition systems with a distributor
- Can be used as a timing interceptor or as a replacement ignition
- Ignition timing mapped against RPM and engine load
- Interpolated values used for RPM and load values between sites
- Optional single map or dual timing maps
- Single map has 15 RPM sites x 15 engine load sites
- Dual maps each have 11 RPM sites x 11 engine load sites
- 1° or 0.5° adjustments
- Dwell adjustment
- Knock sensing indication with optional ignition retard
- Suits 1 to 12-cylinder engines (4-stroke) and 1 to 6-cylinder 2-stroke engines
- Two debounce settings
- High-level or low-level triggering
- Points, reluctor, Hall effect, digital signal or optical triggering
- Works with many pressure sensors (MAP sensors)
- Minimum and maximum RPM adjustments
- Minimum and maximum engine load adjustments
- Diagnostic RPM and load readings
- Add-on knock sensing unit (optional)
- Requires evenly spaced firing between cylinders. For V-twins, you will need two ignition systems and a separate trigger for each cylinder.

be able to obtain the curves from the manufacturer. For other cars, you will need to plot out the existing curve and transfer the resulting timing map to the Programmable Ignition.

Plotting out this timing curve is not hard to do and can, in fact, be done using the Programmable Ignition system itself and a timing light.

In practice, the ignition timing is mapped out in an array of either two 11-RPM by 11-engine load site maps or as a single 15-RPM by 15-engine load site map. Timing arrays (or ignition maps) are the most common method that car manufacturers use to set the ignition advance curve for both RPM and engine load.

Mapping is a way of plotting the advance curve as a series of steps rather than setting an ignition advance or retard value at every possible engine RPM and load value. Thus mapping sets the ignition advance or retard values at specified preset points for both RPM and engine load.

For example, we can specify the timing advance to be 25° at 3000 RPM and 28° at 3400 RPM. However, we do not specify individual values at 3100, 3200 or 3300 RPM. Instead, the advance values at these RPMs are interpolated (ie, calculated), based on the values set for 3000 and 3400 RPM.

At 3200 RPM, the amount of advance is easily calculated because it is exactly in the middle between the 3000 RPM and 3400 RPM sites. The advance change between 3000 RPM and 3400 RPM is 3° (ie, from 25° to 28°) and half of this is 1.5°. So the advance required at 3200 RPM is simply 25° + 1.5° = 26.5°.

Another calculation is required for engine load values that are in-between the specified load sites.

For our Programmable Ignition, if you require two separate engine advance curves then you need to select the 11x11 arrays. If only one advance curve is required, you then have the option of using a 15x15 array for greater accuracy.

By the way, don't confuse the ignition timing map with the MAP (manifold air pressure) sensor. They are two completely different things.

Plotting the timing values

We used the Programmable Ignition, the LCD Hand Controller and a timing light to plot out the ignition timing values for a 1988 2-litre Ford Telstar. We'll describe exactly how this is done in some detail in a later article.

The resulting timing vs RPM values were tabled (Table 1) and then plotted using Microsoft Excel. These files will be available on our website so that you can use the tables and edit the values (just by wiping over the values and rewriting them) to suit your car's engine. It is not really necessary to use Excel though and you can just as easily use a pencil and piece of paper to draw out the map instead.

Fig.2 shows the ignition timing versus RPM and engine load from 1000-5000 RPM. Since we have 11 RPM sites, each RPM site covers a span of 400 RPM.

RPM0 is an extra site and is shown covering the range from 0-1000 RPM. The RPM0 wording is shown on a different line because it is not an actual

		RPM0	Min RPM										Max RPM
	RPM Site		RPM1	RPM2	RPM3	RPM4	RPM5	RPM6	RPM7	RPM8	RPM9	RPM10	RPM11
	Load Site	0	1000	1400	1800	2200	2600	3000	3400	3800	4200	4600	5000
Min load	LOAD1	16	16	18.5	21.5	23	25.5	29	32	36	38	42.5	44
	LOAD2	15	15	17.5	20.5	22	24.5	28	31	35	37	41.5	43
	LOAD3	14	14	16.5	19.5	21	23.5	27	30	34	36	40.5	42
	LOAD4	13	13	15.5	18.5	20	22.5	26	29	33	35	39.5	41
	LOAD5	12	12	14.5	17.5	19	21.5	25	28	32	34	38.5	40
	LOAD6	11	11	13.5	16.5	18	20.5	24	27	31	33	37.5	39
	LOAD7	10	10	12.5	15.5	17	19.5	23	26	30	32	36.5	38
	LOAD8	9	9	11.5	14.5	16	18.5	22	25	29	31	35.5	37
	LOAD9	8	8	10.5	13.5	15	17.5	21	24	28	30	34.5	36
	LOAD10	7	7	9.5	12.5	14	16.5	20	23	27	29	33.5	35
Max load	LOAD11	6	6	8.5	11.5	13	15.5	19	22	26	28	32.5	34

Table 1: these ignition advance values were measured for a 1988 2-litre Ford Telstar using a timing light and the Programmable Ignition itself.

RPM site and cannot be adjusted. It has the same values as RPM1.

RPM0 is shown because it explains what the advance curve is below the minimum RPM1 site while the engine is being started. The same thing happens for RPM above RPM11. In this case, the advance remains at the RPM11 values.

Engine load is shown with LOAD1 as the minimum engine load while LOAD11 is the maximum engine load. LOAD1 is usually accessed when the engine is on overrun while LOAD11 is usually accessed under acceleration or when the car is climbing a hill. The load values were measured using a second hand pressure sensor from an automotive wrecker. These were then converted to load values ranging from 1-11.

The curve can be plotted in three dimensions showing RPM, load and ignition advance. If you use our Excel file, then the curve will be automatically replotted when ever a value is altered.

Using the Hand Controller

As mentioned above, the Hand Controller is used to enter the settings and to enter the ignition map. The values are displayed on the 2-line 16-character LCD screen. There are eight direction pushbuttons, a Run/View pushbutton and a Reset.

The Reset switch is recessed to prevent accidental activation. It is used to return all mapped advance or retard values to 0°. The eight direction pushbuttons alter the values and can configure the display to show the different settings or a different load site.

Finally, the Run/View pushbutton only works in the Timing mode. This mode is selected using a jumper link on the Programmable Ignition Timing Module.

RUN modes

The Timing mode has four possible display modes, selected by pressing the Run/View pushbutton. It selects one of four modes – called SITE, FULL, DIAG and VIEW – in cyclic fashion.

Each display mode shows a slightly different aspect of the mapping sites. One feature in common is that they all display the MAP and the current advance or retard value on the top line, although there is a difference in the displayed value as we shall see.

When the 11x11 maps are selected (from the settings mode), the display will show either **MAP**α or **MAP**β, depending on which map is selected. If the 15x15 map is selected, then the display will only show **MAP**, without the alpha or beta symbols.

Following the MAP legend, the display shows the advance or retard value. The display format depends on whether the setting is for 0.5° or

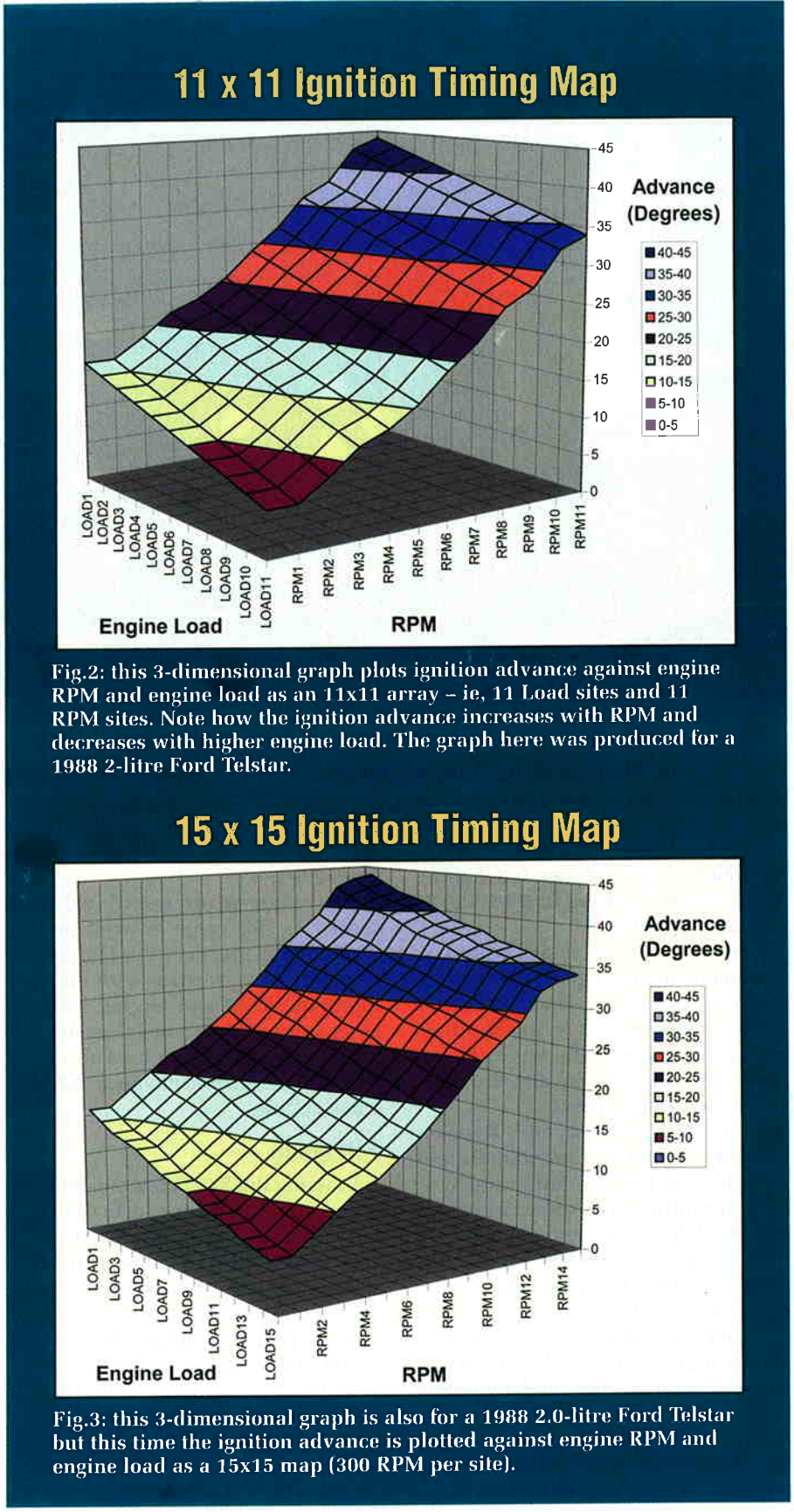
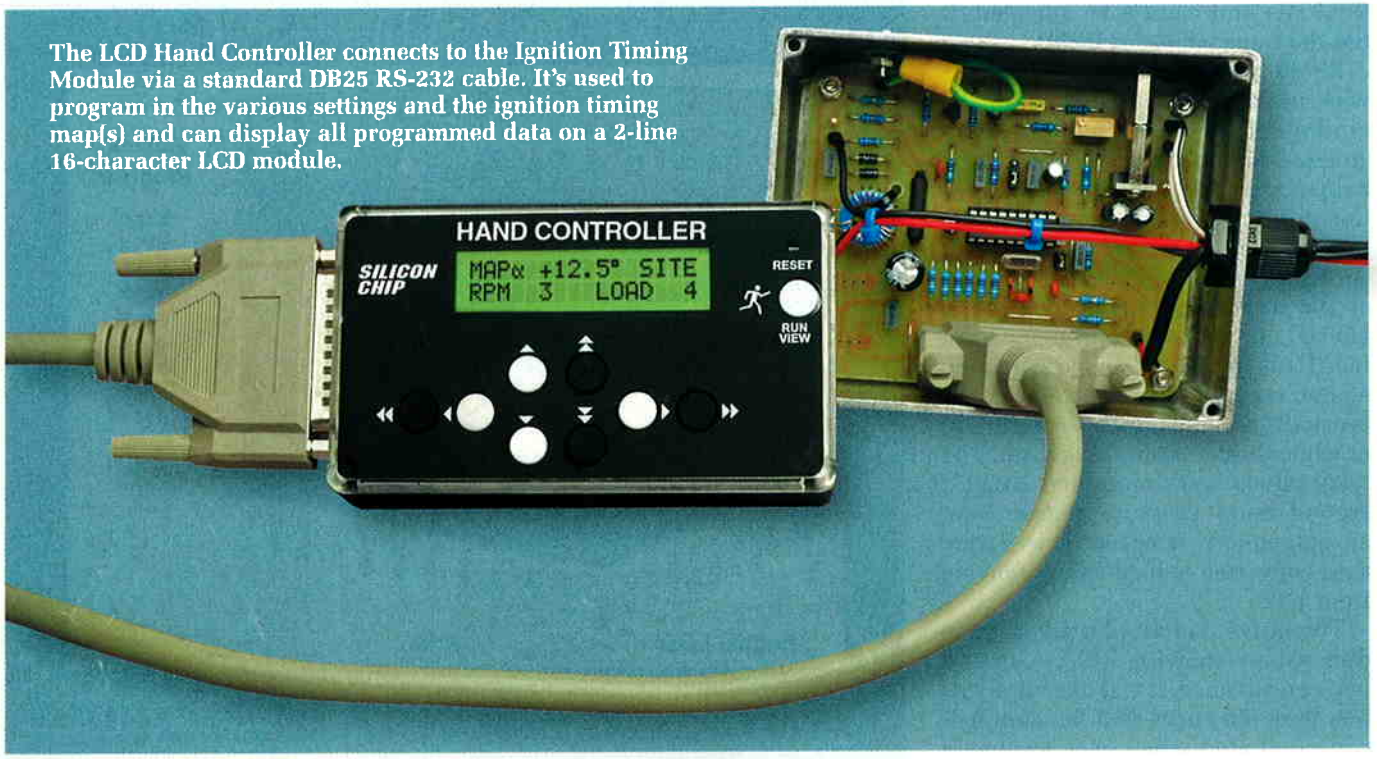


Fig.2: this 3-dimensional graph plots ignition advance against engine RPM and engine load as an 11x11 array – ie, 11 Load sites and 11 RPM sites. Note how the ignition advance increases with RPM and decreases with higher engine load. The graph here was produced for a 1988 2-litre Ford Telstar.

Fig.3: this 3-dimensional graph is also for a 1988 2.0-litre Ford Telstar but this time the ignition advance is plotted against engine RPM and engine load as a 15x15 map (300 RPM per site).



The LCD Hand Controller connects to the Ignition Timing Module via a standard DB25 RS-232 cable. It's used to program in the various settings and the ignition timing map(s) and can display all programmed data on a 2-line 16-character LCD module.

1° resolution. In all cases, a "-" sign indicates a retard value, while a "+" sign indicates an advance value. When there is no change in advance or retard, the value simply shows 0.0 for the 0.5° resolution setting or 0 for the 1° resolution setting.

The advance or retard value is changed using the Up (▲), Down (▼), Step Up (⏫) and Step Down (⏬) pushbuttons. The ▲ and ▼ pushbuttons increase or decrease the setting by the resolution value; ie, by either 0.5° or 1° for each switch press.

By contrast, the ⏫ and ⏬ pushbuttons change the advance/retard value by 2° on 0.5° resolution and by 4° on 1° resolution. The resulting values are stored in memory and remain there even if power is turned off, unless they are changed by the pushbuttons or by the Reset switch.

At the end of the top line, the display shows either SITE, FULL, DIAG or VIEW, to indicate the selected mode. Note that the SITE, FULL and DIAG modes are called the "Run" modes because they show what sites are accessed while the engine is running.

Site mode

The SITE mode is displayed each time the Programmable Ignition is powered up when the Run/View mode is selected with the jumper link. In this mode, the second line shows the current RPM site and the current LOAD site. These are from sites 1-11 when the 11x11 mapping is selected or from 1-15 when the 15x15 mapping is selected.

The advance or retard value is shown as the value entered at that load site. In practice, the LOAD and RPM sites only change with changes in engine RPM and engine load. In other words, this is a real time display that shows the current load and RPM sites and the current advance or retard value setting.

Full mode

Pressing the Run/View pushbutton brings up the FULL mode. In this case, the second line shows the RPM site as before (eg, RPM1) but it also shows the actual position between this site and the next. For example, with the 11x11 ignition timing map (Fig.2), each site is 400 RPM away from the next.

In practice, however, the RPM is measured in 100 RPM steps. As a result, the display shows the RPM 1 position as RPM 1;0, RPM 1;1, RPM 1;2 or RPM 1;3. These values correspond to 1000, 1100, 1200 and 1300 RPM respectively. There is no RPM 1;4 position as this becomes the RPM 2;0 site for 1400 RPM.

If you don't understand this, it will become clearer when we describe how the Programmable Ignition is set up in the forthcoming articles.

Similarly for the LOAD sites, the position within the site is shown after the semicolon (;). Note that the word LOAD is abbreviated to just LD, so that the values fit within the display line.

In the FULL display mode, the advance or retard value is the interpolated value that is calculated for the positions between each load site.

Let's go back to our earlier example and consider the RPM 6 (3000 RPM) and RPM 7 (3400 RPM) sites. At these sites, the advance is 25° and 28° respectively. This means that at RPM 6;0 the advance value will be displayed as +25.0°, while at RPM 7;0 the value will be shown as + 28.0°.

The interpolated value will be shown for RPM values between these two sites. For example, at 3200 RPM (RPM 6;2), the advance value will be +26.5°. Consequently, this is the value that will be shown at site RPM6;2.

Note that this is a simplistic example because we are ignoring the fact that the LOAD value could also be in-between LOAD sites. In that case, both the RPM and LOAD values are interpolated to give the advance or retard value.

Note also that if the advance or retard value is increased or decreased in this mode, it will be the interpolated value that is displayed rather that the site value. The site that will be

changed is the next lowest RPM and LOAD site.

Having said all that, interpolation can be switched off within the settings if required.

Knock sensing

When knock sensing is set, the display shows the modified timing value after knock retard is taken into account. This means that if the display is showing +26.0° and the knock sensing subsequently introduces a 6° timing retard, the display will then immediately show +20.0°. This is the actual advance value used for ignition.

Note that engine knock detection is indicated by an exclamation mark (!) that is positioned between the RPM site value and the LOAD on the second line of the display. The (!) is shown when knock is detected, regardless as to whether the knock retard feature is on or off. The knock symbol is shown in the SITE, FULL and DIAG display modes.

Diagnostic mode

Pressing the Run/View switch again switches to the DIAG mode. This is the diagnostic mode and is very useful when it comes to determining your engine's RPM range, as well as measuring the output range from the MAP sensor.

In this mode, the second line shows the actual RPM with 100 RPM resolution and the actual LOAD value from 0-255. The advance/retard value on the top line normally shows the interpolated value in the same way as the FULL mode.

As mentioned above, interpolation can be switched off and this is useful when measuring the manufacturer's advance curve (more on this in a later article).

Pressing the Run/View pushbutton yet again switches to the VIEW mode. This is not a real-time display because the RPM and LOAD sites do not change with the engine RPM or load. Instead, you can step through each site manually using the Right (▸), Step Right (▸▸), Left (◂) and Step Left (◂◂) pushbuttons.

The ▸ and ◂ pushbuttons increase or decrease the LOAD site value. When increasing the LOAD site value and it reaches its maximum value (either 11 or 15), pressing the switch again causes the RPM site to increase by 1 and the LOAD site to return to 1. In this way,

Specifications

Timing adjustment resolution: 0.5° resolution advance and retard or 1° resolution advance and retard.

Timing adjustment range: ±60° for 12-cylinder engines, ±90° for 8-cylinder engines, ±120° for 6-cylinder engines, ±127° for less than 6 cylinders. Using less than 75% of the limit is recommended to prevent timing "drop-out" with sudden RPM changes.

Timing adjustment accuracy (above Low RPM setting): 0.2% for a 2-cylinder 4-stroke, 0.3% for a 6-cylinder 4-stroke, 0.4% for an 8-cylinder 4-stroke (note: 0.3% is equivalent to 0.12° at 40° advance or retard for a 6-cylinder engine).

Timing update: the update period is the time between successive firings.

Timing calculation period: 700µs maximum.

Timing jitter: ±5µs at 333Hz (5µs is equivalent to 0.3° for a 6-cylinder engine at 10,000 RPM).

Minimum input frequency: 0.6Hz (corresponds to 36 RPM for a 2-cylinder 4-stroke engine, 18 RPM for a 4-cylinder 4-stroke engine, etc).

Maximum input frequency: 700Hz (corresponds to 14,000 RPM for a 6-cylinder 4-stroke, 7000 RPM for a 12-cylinder 4-stroke.

Cylinder settings: 1-12 cylinders for a 4-stroke engine and 1-6 cylinders for a 2-stroke engine.

Minimum RPM setting: 0-25,500 RPM in 100 RPM steps

Maximum RPM setting: indirectly set by RPM/SITE – 0-25,500 RPM in 100 RPM steps.

Minimum load setting: 0-255 in steps of 1 (corresponds to 0-5V).

Maximum load setting: indirectly adjusted by changing loads per site (0-255 in steps of 1).

Debounce adjustment: 0.4ms or 2ms.

Dwell adjustment: 0-25.3ms in 0.2048ms steps (multiplied with voltage below 12V).

Dwell variation with supply: x1 for >12V, x2 for 9-12V, x3 for 7.2-9V, x 4 for <7.2V.

Firing edge selection: low or high.

Spark duration: 1ms.

Map settings: two 11x11 maps (MAPα and MAPβ) or single 15x15 map.

Knock input range: 0-5V (0-1.25V = no retard; 1.25-5V = progressive retard in 16 steps). 9° at 3.75V, 12° at 5V for 1° resolution; 4.5° and 6° respectively for 0.5° resolution.

Knock monitoring (requires an additional knock circuit): monitored for the first 6ms after firing. This period is reduced at higher RPM with the start of dwell. Optional 4000 RPM or 6000 RPM sensing limit. Ignition retard activation (when enabled) is set for a minimum of 10 sparks with the onset of knocking.

Internal test oscillator: 4.88Hz.

Response to low RPM setting: 0-25,500 RPM in 100 RPM steps. Typically set at around 1000 to 2000 RPM.

The Best Laid Plans Of Mice & Men

When we presented our last very popular High Energy Electronic Ignition System, in the December 2005 & January 2006 issues of SILICON CHIP, we stated that "in a future issue we would present a development of the Electronic Ignition to allow ignition timing to be altered. That project will allow the existing timing to be fully mapped on the basis of engine RPM and inlet manifold pressure".

In fact, provision was made on the PC board for the extra parts that would be required to make the system fully programmable. A new program for the microcontroller would complete the system . . . or at least, that was the plan.

It didn't work out. Instead, we have had to effectively split the original PC board into two parts and add a few more components into the bargain.

Now what was that about mice and men? It goes like this:

The best-laid plans o' mice an' men
Gang aft a-gley,
An' lea'e us nought but grief an' pain
For promised joy.

["To a Mouse" by Scottish poet Robert Burns (1759-1796)].

you can step through the entire ignition-timing map.

The same thing happens when decreasing the LOAD site value. After reaching 1, the RPM site value is decreased by 1 on the next switch press and the LOAD site goes to either 11 or 15 (depending on the MAP setting).

The ⏩ and ⏪ switches just alter the RPM sites up or down without altering the LOAD site. In this way you can check the ignition advance or retard settings for each RPM site at a particular LOAD site.

Note that the ▶, ⏩, ◀ and ⏪ pushbuttons do not operate in the SITE, FULL and DIAG modes. In these modes, the sites are only changed in response to engine RPM and load inputs.

Settings

The Settings display is invoked when jumper LK1 in the Programmable Ignition Timing Module is moved to the settings position. This display is used to set up the programmable ignition to suit your engine.

The display will initially show <SETTINGS>. The < and > brackets indicate that each setting can be selected with either the left (◀) or right (▶) pushbutton switch. The values within the settings are then changed using the ▲ and ▼ pushbuttons. These values (except for the oscillator setting) are stored in memory and do not change unless altered using the Up and Down pushbuttons.

Note that the oscillator setting is always off when power is re-applied to the Programmable Ignition.

Pressing the ▶ pushbutton brings up the Cylinder setting. You can then select cylinder values from 1-12 for a 4-stroke engine and from 1-6 for a 2-stroke engine. During this time, the top line of the display will show STROKE and then two numbers – ie, 4 and [2] for 4-stroke 2-stroke engines respectively. Directly below these on the second line is the word CYLINDER and the selected cylinder numbers (the bracketed number is the cylinder value for a 2-stroke engine).

The cylinder value is changed using the ▲ and ▼ pushbuttons. Note that a dash is shown in the two 2-stroke column when odd 4-stroke cylinder numbers are selected, as this is not a valid setting for a 2-stroke engine.

The next four settings are for adjusting the range of the RPM sites and the LOAD sites. These are crucial in insuring you get the full use of the available sites. In other words, there is not much point in having the RPM sites cover a range from 0-25,000 RPM when, for example, the engine does not run above 5000 RPM. In this case, you would only be using 20% of the available RPM sites (ie, RPM 1, RPM 2 and part of RPM3 only) for mapping the advance curve.

The first of these settings is the Minimum RPM. This sets the RPM for the RPM 1 LOAD site. The display shows SET MIN RPM X00 RPM, where the X represents a number from 0-255. Typically, this is set at the idle speed for the car but it may be set differently depending on how you want the ignition curve to operate (more on this in a later article). The settings can be changed from 0 RPM through to 25,500 RPM in 100 RPM steps.

In practice, you would use the DIAG (diagnostic) setting mentioned above to determine the minimum and maximum engine RPM range. Alternatively, you can use the idle and red-line specifications for your engine.

The second setting is for the Maximum RPM. This value of RPM is indirectly set by the value of the RPM per site (RPM/SITE) adjustment, as shown on the top line of the display. It can be set from 0-25,500 RPM in 100 RPM steps.

The second line shows the maximum RPM. This is calculated based on the minimum RPM setting and the RPM/site value. It is shown in the second line of the display as MAX RPM X00 RPM, where X is a number from 0-255. An ERROR indication is shown instead of the maximum RPM if the setting would be over 25,500 RPM.

The reason why we adjust the RPM/SITE value rather than the Maximum RPM directly is because the Programmable Ignition requires a discrete number of 100 RPM steps between each RPM site.

In practice, the RPM/SITE value is altered so that the maximum RPM is at or just over the value required. You can also adjust the minimum RPM setting to achieve the best compromise for the adjustment.

An example may help here using the 11 x 11 map. If, say, the minimum RPM is set at 1000 RPM, the RPM/SITE value can be set to say 400 RPM for a 5000 RPM maximum or to 500 RPM for a 6000 RPM maximum. Thus, if you had a red line of say 5500 RPM, you could set the RPM/site value to 500 for the 6000 RPM maximum. Alternatively, you could lower the minimum RPM value to say 800 RPM, with the RPM/site set to 500 for a 5800 RPM maximum.

The third and fourth settings are for the LOAD sites. Again, in practice, you would use the DIAG (diagnostic) mode to determine the minimum and maximum values from the MAP sensor. The maximum load values occur when the car is accelerating up a hill, while minimum load values are

present under very light throttle conditions and when the engine is being overrun in low gear downhill.

The Minimum Load adjustment can be set from 0-255 in steps of 1. These 0-255 values correspond to the 0-5V output from the MAP sensor. This value is set to the reading obtained in the DIAG (diagnostic) mode when the engine is being overrun.

By contrast, the Maximum Load is adjusted indirectly by changing the loads per site (LOADS/SITE) setting. This can be changed in steps of 1 from 0-255. The second display line shows the calculated maximum load (MAX LOAD) value based on the minimum load and the LOADS/SITE setting. An ERROR indication shows if the calculated maximum LOAD value is over 255.

In practice, the Minimum Load and the LOADS/SITE settings are adjusted so that they cover the range of the MAP sensor output, although they may slightly overlap the required minimum and maximum values.

Other settings that follow these mapping values are:

(1). MAPS: here you can select either the two 11x11 maps (mapα and mapβ) or the single 15x15 map. Note that any ignition values mapped into an 11x11 map will no longer be correct if the map is subsequently changed to a 15x15 array and vice versa. Instead, you have to re-enter the values.

(2). Resolution: this sets the resolution of the advance/retard adjustments and can be either 1° or 0.5°. Once ignition values have been entered into the map on one resolution setting, they will be incorrect if the resolution is changed to the alternative setting.

(3). Response To Low RPM setting: at low RPM, the engine speed can change quite quickly. Because the calculation for RPM can only occur between each detected firing pulse, the response to RPM changes can be too slow and can lag behind the engine. This can noticeably retard the ignition with increasing RPM. The Response To Low RPM setting is included to improve low RPM response, particularly at starting. The downside of this setting is that there is some slight ignition retardation but this is less than 1° for typical low RPM settings.

The RPM value can be set from 0-25,500 RPM in 100 RPM steps. The Low RPM Response operates for RPM below the set value (typically just below idle speed). Above this setting, the standard response to RPM occurs. By contrast, the response at higher RPM is satisfactory because there is only a short period between plug firing and the engine speed will not vary much during this time. Usually, the setting is adjusted so that it operates at engine cranking speed but stops when the engine reaches idle speed. In other cases, it may be necessary to raise this RPM limit so that the engine can rev correctly from idle.

(4). Debounce: the debounce setting affects the trigger input and its resilience to a noisy signal, as can typically occur with points bounce in older car ignition systems. Unless corrected, points bounce can upset the detection of engine RPM and affect the timing. Typically, you can use the 0.4ms debounce setting but the alternative 2ms debounce setting can be selected if the ignition appears to be erratic due to a noisy input sensor signal.

(5). Dwell: dwell is the period during which the ignition coil "charges" before each plug firing. It is alterable from between 0-25.3ms in 0.2048ms steps. We have provided an oscillator feature (see below) that allows the ignition coil to be driven by the Programmable Ignition and the spark produced by the coil monitored. The dwell is then progressively adjusted upwards from 0ms until the spark reaches its maximum voltage. The dwell is then increased slightly above the set value to ensure there is more than sufficient spark when the engine runs.

In addition, the dwell is automati-

Ignition Timing – A Quick Primer

A typical internal combustion engine has one or more pistons that travel up and down inside cylinders to turn a crankshaft. As a piston rises inside its cylinder during the compression stroke, a mixture of fuel and air is compressed. In petrol and gas engines, this fuel-air mixture is then ignited using a spark to drive the piston as it starts its downward stroke.

This ignition must be timed accurately to ensure maximum power and efficiency. If the mixture is fired too late in the cycle, power will be lost because the piston will have travelled too far down in the cylinder for the burning fuel to have maximum effect. Conversely, if the mixture is ignited too early, it will "push" against the piston in the wrong direction as it rises towards top dead centre (TDC).

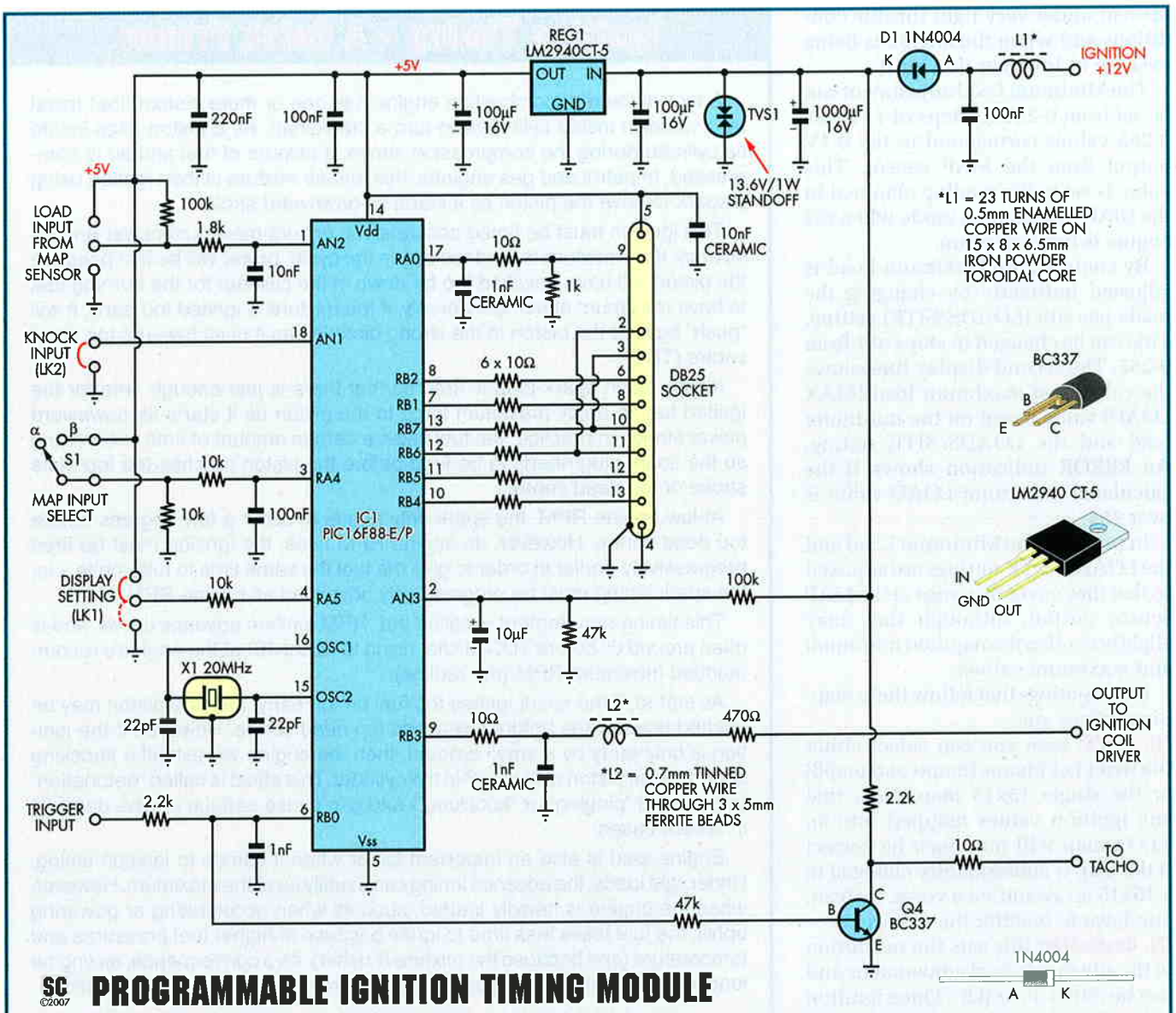
Ideally, each spark plug is fired so that there is just enough time for the ignited fuel to apply maximum force to the piston as it starts its downward power stroke. In practice, the fuel takes a certain amount of time to burn and so the spark plug needs to be fired before the piston reaches the top of its stroke or top dead centre.

At low engine RPM, the spark only needs to occur a few degrees before top dead centre. However, as engine RPM rises, the ignition must be fired progressively earlier in order to give the fuel the same time to fully ignite – ie, the spark timing must be progressively advanced as engine RPM rises.

This timing requirement is called the "RPM ignition advance curve" and is often around 6° before TDC at idle, rising to about 40° at the engine's recommended maximum RPM (the redline).

As stated, if the spark ignites the fuel far too early, then the piston may be pushed downwards before it reaches top dead centre. However, if the ignition is only early by a small amount, then the engine will exhibit a knocking sound as the piston rattles within the cylinder. This effect is called "detonation" (also called "pinging" or "knocking") and can cause serious engine damage in severe cases.

Engine load is also an important factor when it comes to ignition timing. Under light loads, the advance timing can usually be at the maximum. However, when the engine is heavily loaded, such as when accelerating or powering uphill, the fuel takes less time to ignite because of higher fuel pressures and temperature (and because the mixture is richer). As a consequence, as engine load increases, the ignition timing must be retarded to prevent detonation.



PROGRAMMABLE IGNITION TIMING MODULE

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Fig.4: the Ignition Timing Module is based on a PIC16F88-E/P microcontroller. This processes the input trigger, MAP sensor and optional knock sensor signals and provides outputs to drive the Ignition Coil Driver circuit (Fig.5) and a tachometer. It also monitors the Hand Controller's switches and drives the LCD.

cally increased when the battery voltage is low – ie, to x2 for battery voltages between 9V and 12V; to x3 for voltages between 7.2V and 9V; and to x4 for voltages below 7.2V.

(6). Edge: this sets the ignition to trigger from either a low-going input signal edge or a high-going signal. In most cases, a high-going signal edge must be selected but some optical, Hall-Effect and reluctor outputs will require the low-going edge selection.

(7). Knock: this sets the KNOCK retard feature either ON or OFF and sets the LIMIT at either 4000 or 6000 RPM (these settings are all shown on the LCD). Pressing the ▲ and ▼ pushbuttons cycle the selections between these options. The LIMIT setting sets the RPM value at which knock sensing ceases. This is usually set to 4000-6000 RPM because at higher revs, the engine noise drowns out any knocking and so would either be undetectable or would cause false readings.

Note that knocking will only be detected if the separate knock sensing circuit (to be described) is added and a knock sensor is installed on the vehicle.

(8). Diagnostic: this sets the interpolation either ON or OFF. It is normally set to ON and should only be set to OFF when making ignition curve measurements using the Programmable Ignition and a timing light.

(9). Oscillator: this sets the internal oscillator ON or OFF. It's normally OFF but can be set to ON to test the ignition coil spark with varying dwell settings. The oscillation rate is about five times a second (5Hz).

Circuit details

OK, so much for all the fancy features built (or more accurately, programmed) into the unit. Let's now take a look at the circuit details.

The circuit for the Programmable Ignition can be split into three sec-

tions. First, there is the Programmable Ignition Timing circuit, as shown in Fig.4. To this is added an input trigger circuit, depending on the ignition trigger used – see Fig.6. This can be either points, optical, Hall effect or reluctor, or can be taken from the engine management unit (EMU).

Finally, a separate circuit, controlled by the Programmable Ignition Timing circuit, drives the ignition coil – see Fig.5.

The LCD Hand Controller, to be described in Pt.2, is a completely separate unit which connects to the Programmable Ignition Timing module via a DB25 cable. As stated, it's used only during the setting-up procedure, after which it is no longer required unless you wish to reprogram the system (eg, to alter the timing map).

The main circuit (Fig.4) is based on IC1 which is a PIC16F88-E/P high-temperature microcontroller. This micro processes the input trigger and MAP sensor signals and provides an output to drive the Ignition Coil Driver circuit. It also drives the LCD module in the Hand Controller and monitors the Hand Controller's switches.

Timing signals for IC1 are provided by crystal X1. This sets the internal oscillator to run at 20MHz, which enables the software programmed into IC1 to run as fast as possible.

In operation, IC1 accepts the ignition trigger signal at its RB0 input (pin 6) and drives its RB3 output to switch the ignition coil (via the driver circuit) accordingly. As shown, the RB0 input is protected from excess voltages by a series 2.2kΩ resistor, which prevents excessive current flow in IC1's internal clamping diodes. Clamping occurs when the voltage goes below 0V or if it goes above the +5V supply (ie, the input is clamped to -0.6V or +5.6V).

The 1nF capacitor at the RB0 input shunts transient voltages and high-frequency signals, to filter false timing signals.

Transistor Q4 is also driven from the trigger input. The transistor is used to provide a tachometer output at its collector. In operation, Q4's collector is normally held high via a 2.2kΩ pull-up resistor but switches low each time the transistor turns on (ie, when the trigger input is high).

Q4's collector output can be used to drive most modern tachometers. However, an impulse tachometer (now very rare) requires a different connection and this type should operate when connected to the ignition coil's negative terminal.

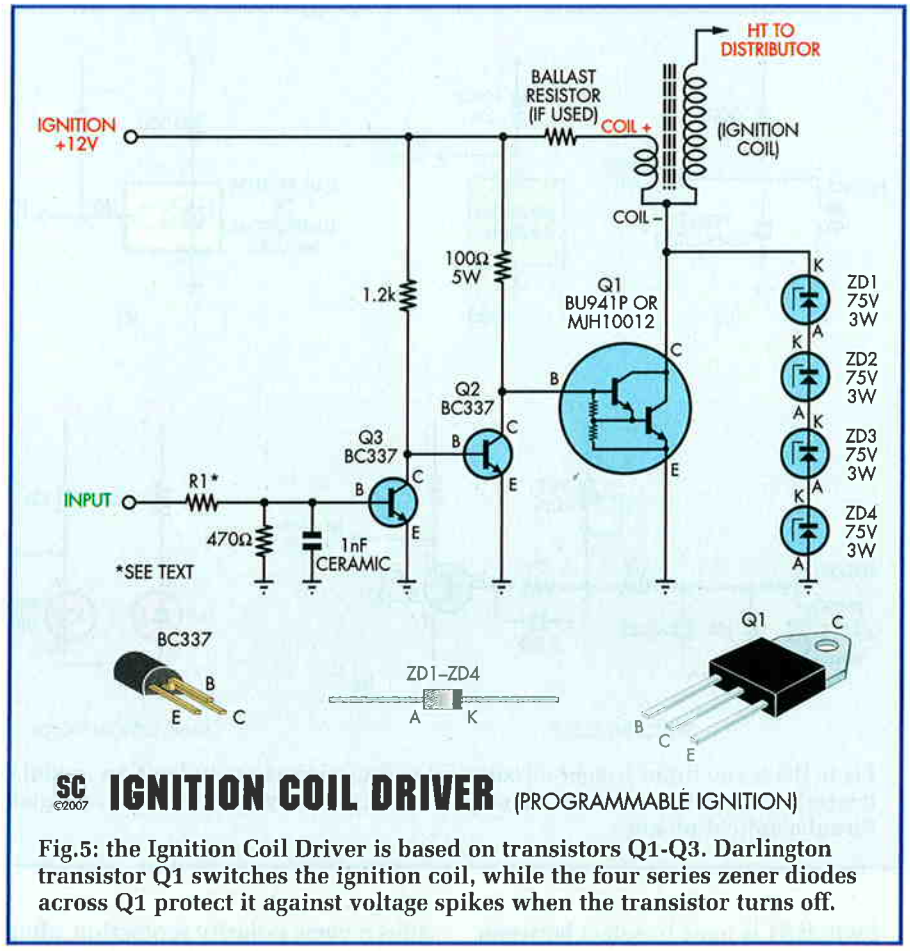


Fig.5: the Ignition Coil Driver is based on transistors Q1-Q3. Darlington transistor Q1 switches the ignition coil, while the four series zener diodes across Q1 protect it against voltage spikes when the transistor turns off.

MAP sensor

The MAP sensor signal is applied to the analog AN2 input of IC1 via a 1.8kΩ resistor. A 10nF capacitor filters out unwanted high-frequency signals to prevent false readings.

In operation, the AN2 input measures an input voltage ranging from 0-5V and converts this to a digital value ranging from 0-255. This is the value that's read from the DIAG (diagnostic) display.

Note that +5V supply and ground rails are provided for the sensor. When the Sensym sensor is used, it can be directly mounted on the PC board used for the Programmable Ignition Timing Module.

The optional knock sensor signal is applied to IC1's analog AN1 input (pin 18). As before, this input accepts signal voltages from 0-5V and converts them to digital values.

Conversely, if the knock sensing circuit is not used, this input must be tied to ground using jumper link LK2 to disable the knock sensing function.

The third analog input at AN3 (pin 2) is used to monitor the +12V ignition supply. As shown in Fig.4, this supply voltage is divided down using 100kΩ and 47kΩ resistors and filtered using a 10µF capacitor before being applied to the AN3 input. This divider effectively converts the supply voltage to a 0-5V signal which is then used to determine if the dwell period should be increased to compensate for a low supply voltage.

Note that the voltage across D1 is accounted for in this measurement.

Link LK1 selects either the timing map display or the settings display. In the settings position, the RA5 input is tied to ground via a 10kΩ resistor. Conversely, when LK1 is in the timing position, RA5 is tied to 5V via the 10kΩ resistor.

Note that the RA5 input differs from the other inputs in that it cannot be directly tied to one of the supply rails otherwise the micro could latch up. The 10kΩ input resistor eliminates this problem.

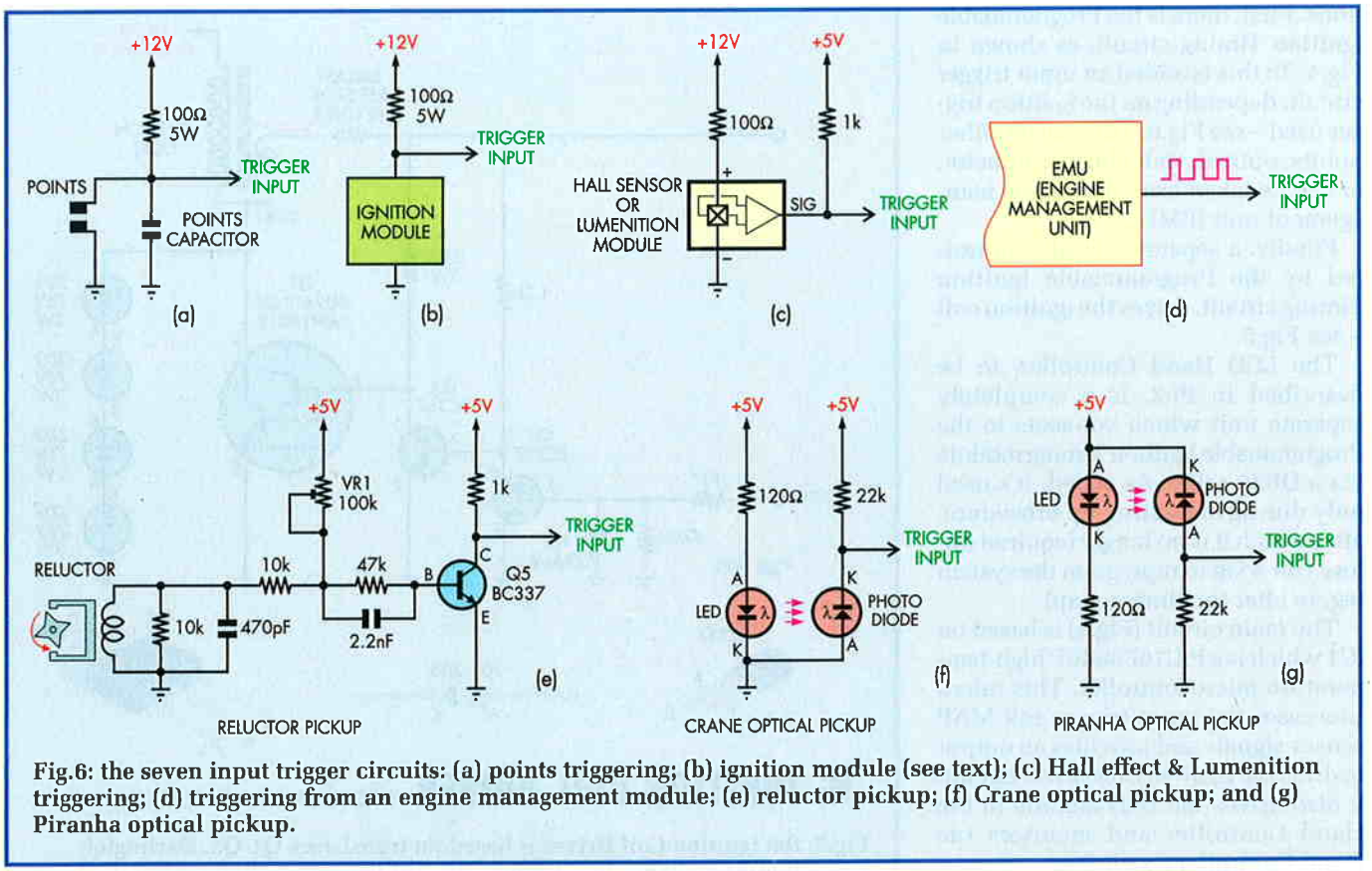


Fig.6: the seven input trigger circuits: (a) points triggering; (b) ignition module (see text); (c) Hall effect & Lumenition triggering; (d) triggering from an engine management module; (e) reluctor pickup; (f) Crane optical pickup; and (g) Piranha optical pickup.

Switch S1 is used to select between the two 11x11 timing maps. When S1 is open, RA4 is pulled low via the 10kΩ resistors and mapα is selected. Conversely, when S2 is closed, RA4 is pulled to +5V and mapβ is selected.

Note that this switch operates only when the 11x11 maps are selected using the LCD Hand Controller. It has no effect if a 15x15 map is selected.

Driving the LCD

Pins 7, 8 & 10-13 of the microcontroller are used to drive the LCD module in the Hand Controller (via a DB25 connector). The 10Ω resistors in series with these outputs act as stoppers to keep RF signals out of IC1.

In addition, the RA0 input at pin 17 monitors the switches from the Hand Controller. The associated 1kΩ resistor pulls the input voltage to 0V unless a switch is closed, at which point the line is pulled high to +5V. The 10nF and 1nF capacitors filter out RF signals.

Power supply

Power for the circuit is derived via the ignition switch. This supply is then filtered using inductor L1 and the 100nF capacitor. Diode D1 provides reverse polarity protection, after which the supply is decoupled using a 1000µF capacitor.

As a further precaution, the circuit is protected from voltage spikes using transient voltage suppressor TVS1. This clamps any high voltages that may otherwise damage following components.

Following TVS1, the supply is regulated to +5V using regulator REG1. This is a low-dropout device and is used here to ensure that a regulated +5V supply is maintained during starting when the battery voltage can drop well below 12V.

A 100µF capacitor decouples the regulator's output, while a 100nF capacitor (located close to pin 14 of IC1) shunts high frequencies to ground.

Ignition coil driver

Fig.5 shows the Ignition Coil Driver circuit. It's fairly straightforward and is based on transistors Q1-Q3.

Q1 is a Darlington transistor specifically made for ignition systems. It's capable of handling currents in excess of 10A and voltages exceeding 400V. As shown, four 75V zener diodes (ZD1-ZD4) are connected in series between its collector and emitter terminals. These protect the transistor from excess voltages by clamping its collector at 300V, which is well within its rating.

The circuit works like this: when the input signal is low (or there is no signal), transistor Q3 is off, Q2 is on (due to base current through the 1.2kΩ resistor) and Q1 is off. Conversely, when the input subsequently switches high, Q3 turns on and switches Q2 off by pulling its base to ground. As a result, Q1 turns on and current flows through the primary winding of the ignition coil.

The ignition input signal now subsequently switches low again and so Q3 immediately turns off due to the 470Ω resistor between its base terminal and ground. And when that happens, Q2 switches on and Q1 switches off, interrupting the current through the ignition coil.

As a result, the coil's magnetic flux rapidly collapses and this generates a high voltage in the secondary to fire one of the spark plugs. The 1nF capacitor on Q3's base is there to suppress any RF signals that may otherwise be injected when the current through the ignition coil is interrupted (ie, when Q1 switches off).

Resistor R1 is included to make the module more versatile. In our application, R1 is not used and is replaced with a wire link. For other applications, where a separate ignition coil driver is required, R1 will be required. Typically, a 470Ω resistor would be used for a 5V drive signal, while a 1.2kΩ resistor would be used for a 12V drive signal.

Finally, the module can also be configured to drive transistor Q1 when the input signal switches low. In this case, Q3 is left out of circuit and a link installed between the pads on the PC board for its base and collector leads. The 1.2kΩ resistor pull-up is also removed from circuit.

Trigger inputs

The Programmable Electronic Ignition is configured for the appropriate trigger input during construction. The seven possible input circuits are shown in Fig.6.

The points trigger is shown in Fig.6(a) and includes a 100Ω 5W wirewound resistor connected to the 12V supply. This resistor provides a "wetting" current for the points to ensure there is a good contact between the two mating faces when they are closed. The wetting current is sufficient to keep the contacts clean but not so high as to damage them.

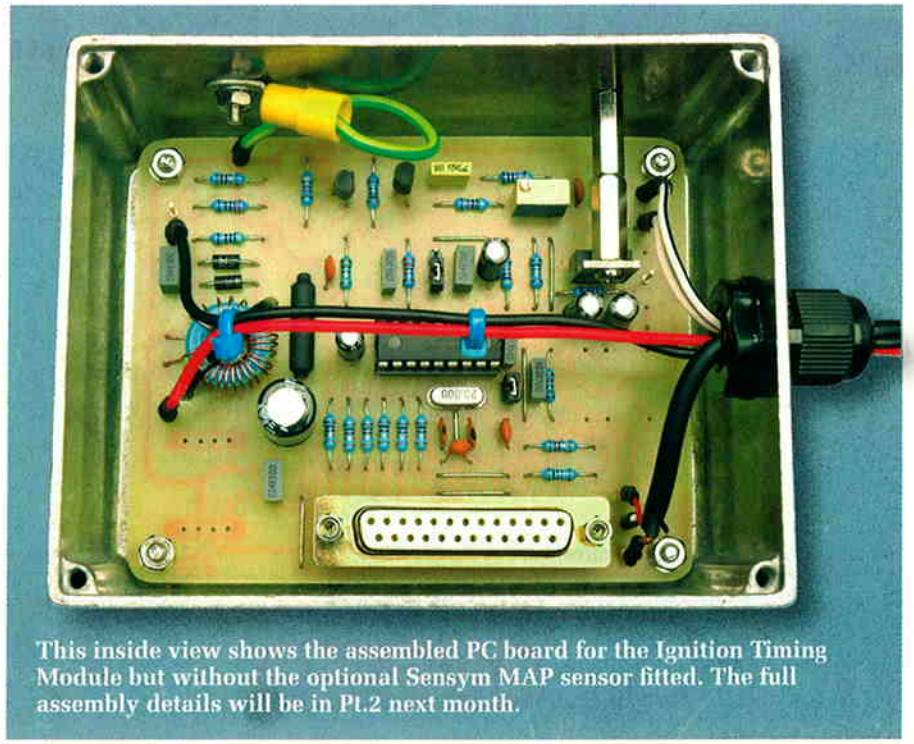
The ignition module version is shown in Fig.6(b). This is essentially the same as the points input except that a transistor inside the ignition module switches the input to ground instead.

This type of input has been included because some electronic ignition systems do not provide access to the actual trigger (usually a reluctor) and the only output is the ignition coil driver transistor. In this case the coil is replaced with the 100Ω resistor to provide the necessary pull-up to +12V when the transistor is off.

Fig.6(c) shows the Hall Effect trigger. It uses a 100Ω current-limiting resistor to feed the Hall sensor, while the 1kΩ resistor pulls the output voltage to +5V when the internal open-collector transistor is off. Conversely, the output signal is pulled to 0V when the internal transistor is on.

Note that the same circuit is used for the Lumenition optical module.

The engine management input circuit is shown in Fig.6(d) and is quite simple. Its 0-5V output signal connects to the trigger section of the main circuit in Fig.4.



This inside view shows the assembled PC board for the Ignition Timing Module but without the optional Sensym MAP sensor fitted. The full assembly details will be in Pt.2 next month.

Reluctor sensors are catered for using the circuit in Fig.6(e). These produce an AC signal and so require a more complex input circuit.

In this case, transistor Q5 switches on or off, depending on whether the reluctor voltage is positive or negative. It works as follows. Initially, with no reluctor voltage, Q5 is switched on via current through VR1 and a 47kΩ resistor. The voltage applied to Q5's base depends on the 10kΩ resistor across the reluctor coil and the internal resistance of the reluctor.

Trimpot VR1 is included to provide for a wide range of reluctor types. In practice, VR1 is adjusted so that Q5 is just switched on when there is no signal from the reluctor. The 10kΩ resistor provides a load for the reluctor, while the 470pF capacitor filters any RF signals that may have been induced.

The 2.2nF capacitor ensures that Q5 quickly switches off when the reluctor signal goes negative.

Finally, Fig.6(f) & Fig.6(g) show two different optical pickup circuits. Fig.6(f) is for a module that has a common 0V supply connection (eg, Crane), while Fig.6(g) is for a module that has a common positive supply (eg, Piranha). In each case, current for the LED is supplied via a 120Ω resistor, while the photodiode current is supplied via a 22kΩ resistor.

Software

The software for the Programmable Ignition is the largest and most complex we have developed to date. In all, the final assembler code totals some 6020 lines to perform all the necessary functions, including monitoring the ignition trigger and pressure sensor signals and providing an output based on the ignition timing map.

Basically, the software includes several multiply and divide routines (some 24-bit) to calculate the timing, based on the RPM and load site. These routines are also used to calculate engine RPM and the interpolated advance/retard values and must be performed constantly to maintain the correct timing as engine RPM and load vary.

We managed to perform all the required calculations in under 1ms – fast enough for high revving engines.

A significant part of the software has also been devoted to the many functions accessible via the Hand Controller and to allow the Hand Controller to be used while the engine is running.

In the end, we used all the data memory space of the PIC16F88 to store the ignition timing maps and the adjustable parameters, along with some 97% of the program memory. SC

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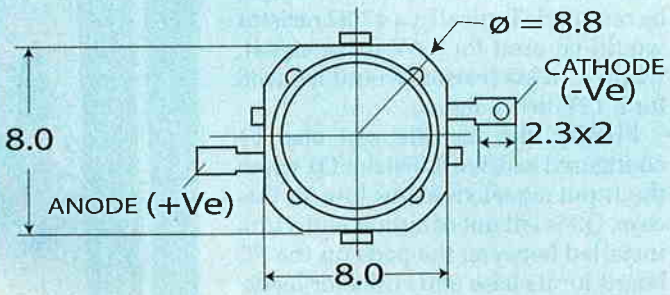

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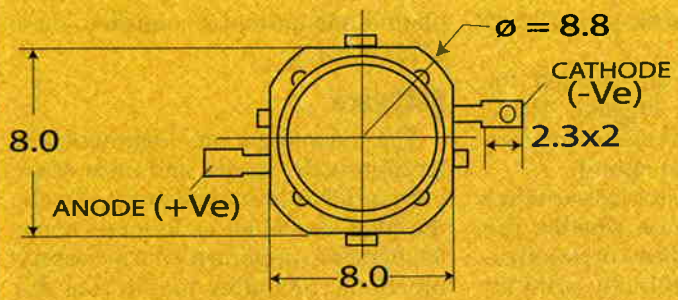

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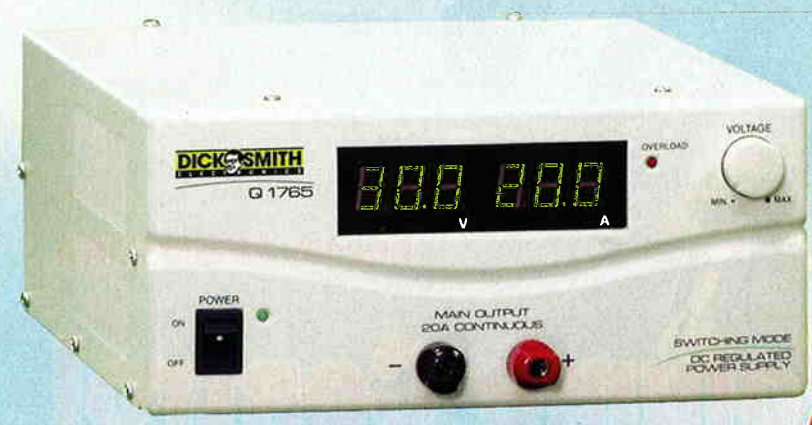

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Pt.2: By PETER SMITH

Remote Volume Control & Preamplifier Module

Second article completes the construction & gives the set-up procedure

WE'VE PRESENTED the Remote Control & Preamplifier project as a stand-alone module because we believe that many constructors will want to build it into an existing case. It is designed to fit flush behind a front panel, hence the LEDs and the rotary encoder are located along the front edge of the board. However, all of these devices can be mounted independently on a panel and wired back to the PC board via short flying leads if desired.

Note that if the infrared receiver includes an external metal shield (see photo), then steps must be taken to ensure that it is insulated from the chassis. We suggest a short strip of insulation tape on the inside of the front panel, with a hole cut out to match the hole in the panel. Do not rely on the paintwork to provide insulation!

The display board should be mounted to the right side or above the main board (ie, away from the audio section) on standoffs behind an appropriate cutout. Additional header sockets (or cut-down 40-pin IC sockets) can be stacked vertically to increase the display height for a flush fit. Both the red and blue displays look great with tinted filters!

As mentioned earlier, three different power supply configurations are possible. You could also power the unit from an existing regulated DC source if available. The minimum requirements are: ±15V @ 20mA and +5V @ 120mA. Note that the two (analog & digital) supplies must share a common ground. This means that if they're located on physically separate PC boards, their grounds must be cabled separately to the single "GND" input at CON1.

Mains wiring

As usual, all 240VAC wiring must be carried out in a safe and professional manner, meaning that we're assuming that you already have the relevant expertise or can obtain assistance from someone who has. **Most importantly, the assembly must be housed in an earthed metal enclosure. The mains earth must be properly connected to this chassis and this can be achieved via a double-ended 6.3mm spade lug fastened securely to the base with an M4 x 10mm screw, shakeproof washer and two nuts – see Fig.16.**

A basic wiring layout is shown in Fig.14. The mains section of the wiring will obviously need to be amended if the module is to coexist with a power amplifier, which will at least share the mains input socket and power switch. Note that if using a separate, chassis-mounted transformer, alternative arrangements must be made for mains fusing. This is best achieved by using an IEC socket with an integral fuse.

Once the mains wiring has been completed, go back and check that each connection is secure and well insulated. If necessary, use heatshrink

tubing to completely cover any exposed terminations. That done, use your multimeter to check continuity between the earth pin of the mains plug and any convenient point on the chassis that is devoid of paint.

This check must be repeated later when the case is assembled. At that time, use your meter to check that all panels of the case are earthed – without exception!

Low-voltage wiring

As a first step, disconnect the mains cord to prevent mishaps while working under the hood. You can then complete the assembly by running all the low-voltage wiring.

If a separate transformer has been used, its two secondary (15VAC) windings must be terminated at the transformer input (CON1) of the power supply board. Twist the wires together and keep them as short as possible to reduce radiated noise.

Next, connect the +15V, -15V & GND outputs at CON2 and +5V at CON3 on the power supply to the matching inputs at CON1 & CON2 of the Remote Volume Control & Preamp module. Note that the GND output at CON3 on the power supply is not used!

Use only heavy-duty hook-up wire for the job. Take great care to ensure that you have all of the connections correct – a mistake here may damage the control module. We suggest four different cable colours to reduce the chances of a mistake!

If you wish to be able to control left/right balance from the front panel, then you'll also need to install a pushbutton switch. This will enable you to use the rotary encoder for both volume and balance adjustments. The terminals of the switch are simply wired between the BALANCE and GND inputs at CON3. Having said that, balance adjustment is a rare requirement after initial setup (which would be done via remote control), so most constructors will not need this switch.

The module also provides a second switch input at CON3 labelled CHANNEL. This is intended for a possible future multi-channel upgrade and should not be connected, as it currently has no function.

Use good quality shielded audio cable for all the audio connections. Terminate one end of the cables in RCA plugs for connection to the control module's inputs and outputs. Depending on your requirements, you may wish to fit chassis-mount RCA sockets at the other end and mount these on the rear of your case.

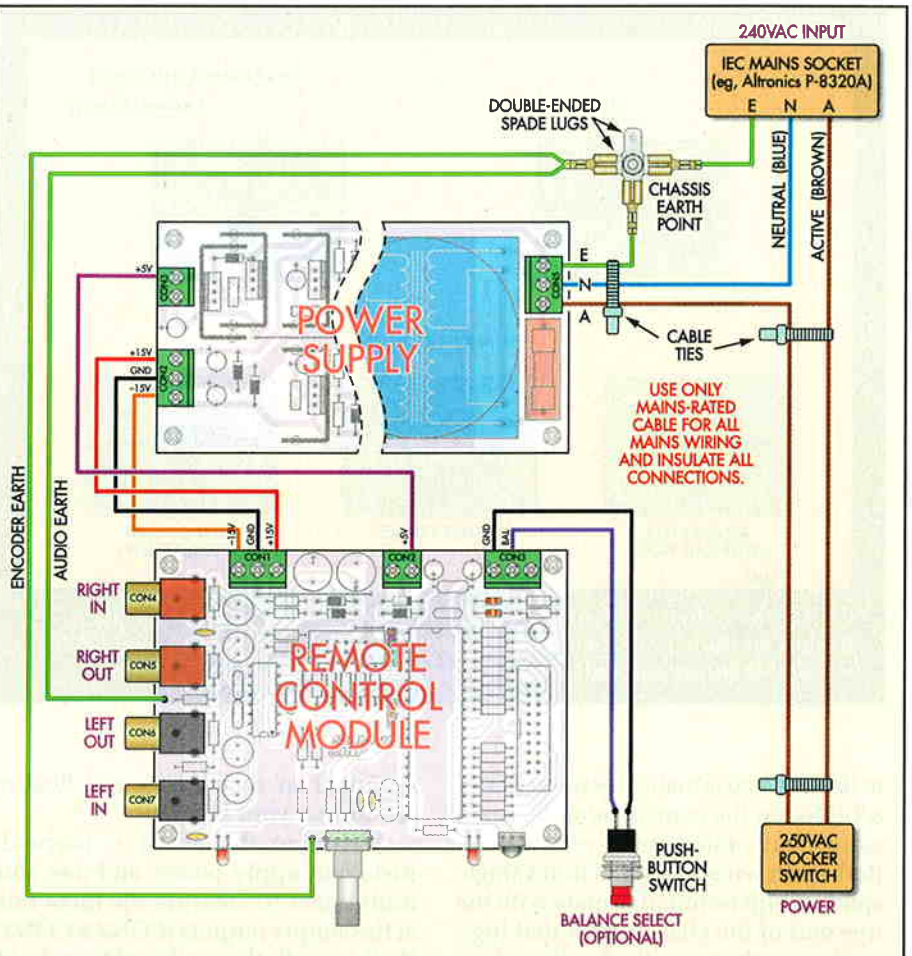


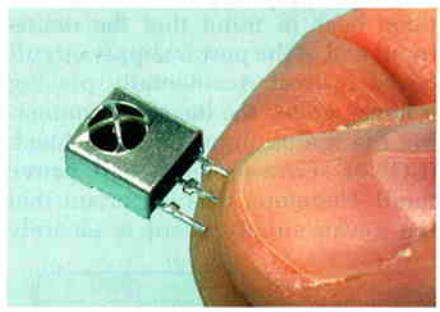
Fig.14: follow this basic diagram when hooking up your module. Use heavy-duty hook-up wire for all of the low-voltage power supply connections. For the mains side, use only mains-rated cable and be sure to keep if well away from the low-voltage side. A few strategically placed cable ties will keep everything in position, even if a wire should happen to come adrift!

Finally, you'll need to make up the cable for the main board to display board connection. This is simply a length of 20-way IDC ribbon cable terminated with 20-way plugs at either end (see photos). We used a 12cm length for the prototype but we expect that if could be at least twice as long without causing any problems. Avoid routing the cable close to the analog section of the control module.

Earthing

So far, you should have just two wires connected to the chassis earth point – the mains earth wire from the IEC socket and a second wire to the "E" input (at CON5) of the power supply. Now run an additional mains-rated green/yellow earth wire from the pad just to the left of the rotary encoder to the chassis earth point. This solidly earths the body of the encoder to protect the microcontroller from static discharge.

To earth the audio ground, run another wire from the chassis earth point



If your infrared receiver module has a metal shield like this one, then be sure to insulate it from the front panel as described in the text.

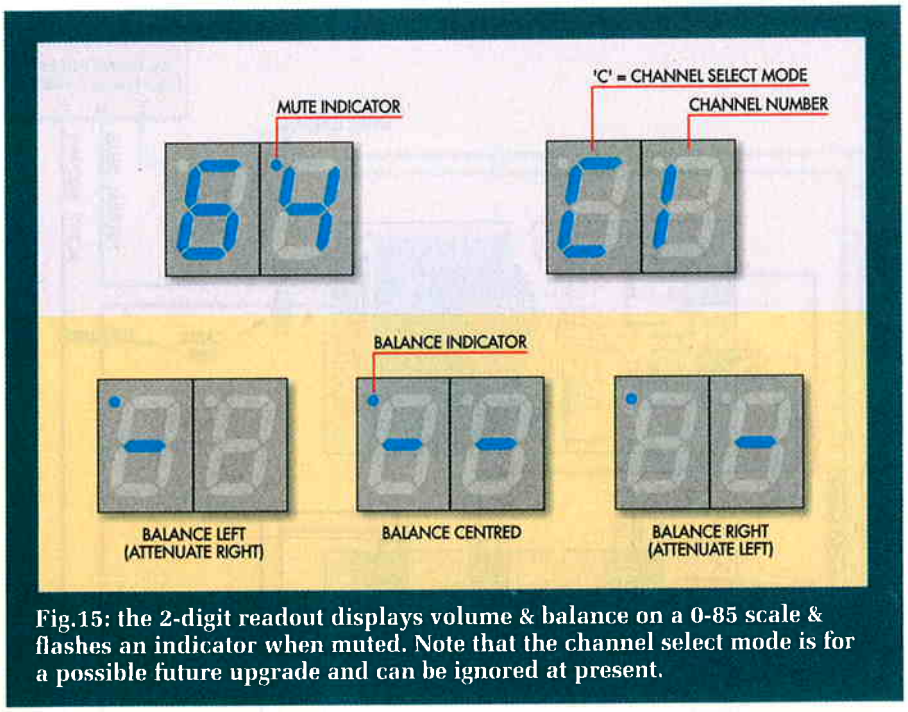


Fig.15: the 2-digit readout displays volume & balance on a 0-85 scale & flashes an indicator when muted. Note that the channel select mode is for a possible future upgrade and can be ignored at present.

to the free pad situated between CON5 & CON6 on the control module, again using mains-rated green/yellow wire. Both earth wires should fit into a single spade crimp terminal to mate with the free end of the chassis-mounted lug.

This earthing method will reduce the chances of creating an audible "earth loop" in your system but success is not guaranteed! For example, if your power amplifier also earths the audio signal, an earth loop will exist once the two are hooked together. This may or may not be a problem.

If you notice more hum in your audio system after connecting the preamp, then try disconnecting the earth wire to the control module. **Never, ever, disconnect the mains earth from the chassis!**

Testing

Before applying power for the first time, bear in mind that the mains input end of the power supply circuit board is live! Accidentally placing a finger under the board or contacting the mains input terminal block (CON4) screws might well prove fatal! Therefore, it is important that the power supply board is securely mounted in a chassis – not floating around on your bench!

Assuming the board is correctly installed, apply power and use your multimeter to measure the three rails at the supply outputs (CON2 & CON3). If all is well, the +15V, -15V and +5V rails should all be within ±5% of the rated values.

Now measure between pins 10 & 12 and then pins 10 & 13 of IC1's socket on the control module. You should get readings just below the ±15V levels measured earlier. Finally, check between pins 5 & 4; again, the reading should be just below the earlier +5V measurement.

Now switch off and allow about 30 seconds for the 1000µF filter capacitors to discharge. You can then insert IC1 & IC2 in their sockets, making sure that the notched (pin 1) ends line up with notches in the sockets!

Before moving on, you must now program the microcontroller (IC2) if it's blank – see the "Microcontroller Programming" panel.

Initial setup

Once construction and testing are complete, a simple setup procedure must be followed to prepare the module for use. Before beginning, make sure that you've set up your remote control as per the information presented last month in the "Universal Infrared Remote Controls" panel.

First, check that the power is switched off, then install jumper shunts on JP1 & JP2 (see Table 1) and JP3 pins 1-2 (Table 2). **A jumper must also be installed on CON8 pins 1-3 (see Fig.7 and photos) at all times except when the microcontroller is being programmed.** Note that if this jumper is missing at power up, the display will flash an error code of "90".

Now apply power while observing the "Ack" LED. It should flash five times to indicate that the unit is in set-up mode. The 7-segment display should be blank, except for the the "mute" indicator continuously flashing.

Next, point your remote at the onboard infrared receiver (IC3) and press the numbers "1" or "2" twice. It's significant which of these numbers is chosen. A "1" enables display blanking, meaning that the display will go blank eight seconds after each volume or balance adjustment. Conversely, "2" disables this feature, causing the display to be always on.

On the second press, the "Ack" LED should flash five times again, indicating that the code was received and the chosen equipment address (TV, SAT, AUX, etc) successfully saved. You should now power down the unit and remove the setup jumper (JP1) only. This procedure can be repeated in the future should you wish to change the equipment address or display blanking option.

In use

As mentioned elsewhere in this article, volume span is effectively 127dB (-95.5dB to +31.5dB). As the PGA2310 supports 0.5dB gain steps, there are 255 steps from minimum to maximum volume. To fit this on a 2-digit readout and make it more intelligible, the level is scaled down to a 0-85 range by dividing it by three. The result is accurate to 1.5dB, so you'll need to adjust the volume/balance by three points before you see a change in the readout. Note that "64" corresponds to 0dB (unity) gain – values below this attenuate the input signal, whereas those above it amplify.

To increase or decrease the volume,

JUMPER	IN	OUT
JP1	SETUP	NORMAL
JP2	0.5dB STEPS	1.5dB STEPS

Table 1: jumpers must be installed on both JP1 & JP2 during the initial setup.

JP3 POSITION	INTERFACE ON CON8
1-2	ISP (DEFAULT)
2-3	SPI (FUTURE MULTI-CHANNEL UPGRADE)

Table 2: jumper JP3 should be installed in the 1-2 position.

siliconchip.com.au

hit the "Vol Up" or "Vol Down" buttons on your remote, or turn the rotary encoder. With jumper JP2 installed, each press (or click of the encoder) moves the volume by just 0.5dB. If the remote's button is held down so that it automatically repeats, the adjustment steps jump to 1.5dB after one second.

Some audio systems may not require the fine 0.5dB adjustment steps. To increase the steps to 1.5dB for every button press or click, remove jumper JP2. In this case, holding down the remote's buttons makes no difference to the step size, which always remain at 1.5dB.

To adjust the balance between the left and right channels, use the "Ch Up" and "Ch Down" buttons on your remote instead. Alternatively, press the optional front-panel "Balance" button and use the rotary encoder. Each press or click adjusts the level by 0.5dB, regardless of the state of JP2. However, holding down the remote's button for more than one second will case a temporary shift to 1.5dB adjustment steps.

When in balance adjustment mode, the left inverted decimal point flashes (see Fig.15). Two dashes on the LED displays indicate that the balance is centred.

Hitting the "Ch Down" button moves the sound stage left. On the first two presses, a single dash is shown in the left digit position, indicating the direction of "movement". Likewise, one or two presses of the "Ch Up" button from the centred position results in a single dash in the right digit position.

Subsequent presses display a number indicating the relative attenuation level of the opposing channel. For example, if the current volume level is set to 50 and the balance is favouring the left side and reads 5, the actual levels are: left = 50, right = 45. After four seconds of inactivity, the unit automatically reverts to volume adjustment mode. To bypass the four-second delay and immediately exit balance mode, use the volume up/down buttons on your remote or press the "Balance" button again.

Both channels are simultaneously adjusted when the volume is increased or decreased, maintaining the balance separation. Note that when either channel reaches the maximum volume setting (ie, 85), further commands to increase the volume are ignored.

When one channel reaches the minimum volume position (0), further commands will continue to decrease the volume in the other channel until both are at minimum, if they are not identical. Increasing the volume from this minimum position restores the original balance separation.

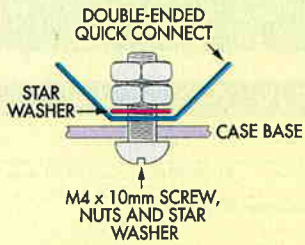
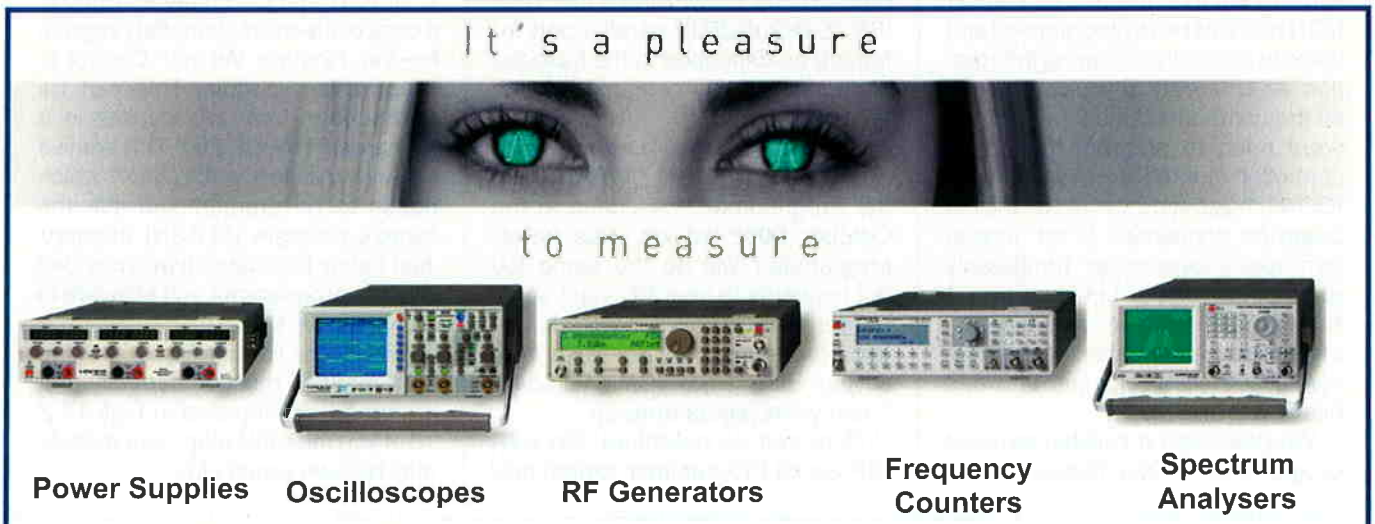


Fig.16: the mains earth lead must be securely attached to the base of the metal chassis. Here's how to assemble a suitable earthing point for attaching two spade lugs. The two nuts lock the assembly in place.

Muting

Muting is achieved by hitting the



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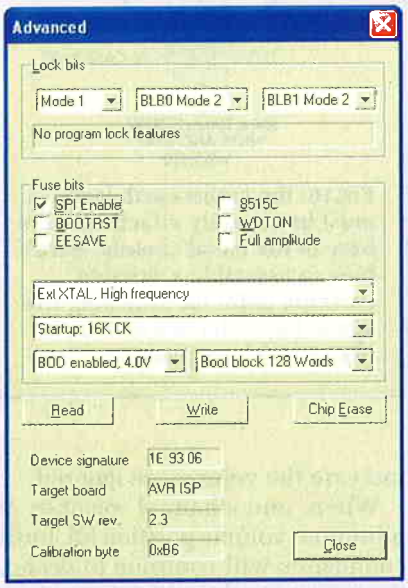

Fig.17: here's how to set the fuse bits in AVR Prog, as used with the AVR ISP Serial Programmer. Once you've set all of the options exactly as shown, click on the "Write" button.

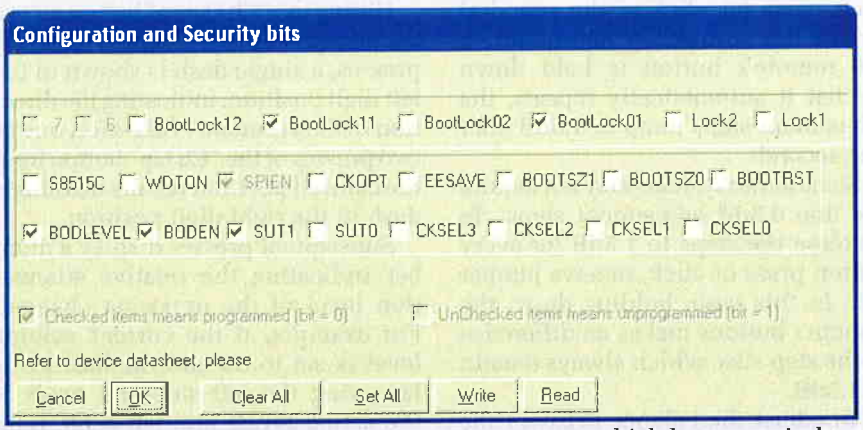

Fig.18: the parallel port programmer uses PonyProg, which has an entirely different fuse configuration menu. Again, copy this example and hit the "Write" button.

IF YOU'RE BUILDING this project from a kit, then the microcontroller (IC1) will have been programmed and you can ignore the following information. Alternatively, if you've sourced all the components separately, then you'll need to program the microcontroller yourself. A 10-way header (CON8) has been included on the PC board for connection to an "in-system" type programmer. Temporarily remove the jumper between pins 1 & 3 of CON8 to allow connection of the programming cable. Also, make sure that there's a jumper between pins 1 & 2 of JP3.

We described a suitable low-cost programmer in the October 2001 edition of SILICON CHIP. Kits for the programmer are currently available from Altronics (Cat. K-2885), on the web at **www.altronics.com.au**. Note that if you are using this particular programmer, the "Atmel AVR ISP" software described in the instructions is no longer available. A suitable alternative, named "PonyProg", is available free from **www.lancos.com**. Set up PonyProg for the "AVR ISP (STK200/300)" parallel port interface as described in the included documentation for compatibility with the programmer.

Some readers may also be familiar with the more recent "AVR ISP Serial Programmer", described in the October 2002 edition. This newer programmer will do the same job but connects to your PC via a serial (rather than parallel) port. Kits for this programmer are available from Jaycar Electronics (Cat. KC-5340) – see **www.jaycar.com.au**.

Note that as published, the AVR ISP Serial Programmer cannot program the ATMega8515 – the code in the programmer's on-board micro must first be updated. An update is available from the SILICON CHIP website. If you've purchased your programmer as a kit, this update will already have been performed.

Once you have a suitable programmer, together with the necessary cables and Windows software to drive it, all you need to complete the job is a copy of the microcontroller program for the Remote Volume Control & Preamplifier module. This can be downloaded from our website in a file named "DAVOL.ZIP". This archive contains the file "DAVOL.HEX", which needs to be programmed into the micro's program (FLASH) memory. Just follow the instructions provided with the programmer and software to complete the task.

Finally, the various fuse bits in the ATmega8515 must be correctly programmed, as depicted in Figs.17 & 18. If you miss this step, your module may behave erratically!

"Mute" or "12" buttons, depending on your model of remote. Hitting the mute button a second time immediately restores the original volume level, while pressing the "Vol Up" button restores the volume level and simultaneously increases it by one step.

Note that pressing "Vol Down" while muted does decrease the volume level shown on the display but it doesn't turn the muting off. This allows you to wind down the volume to a respectable level first – perhaps when you've been caught out with the wick wound up far too high! Muting is indicated by the flashing of the second inverted decimal point (Fig.15, top left), which will continue to flash even during display blanking (when enabled).

Multi-channel upgrade

Finally, we've reserved buttons 1-6 and the optional "Channel" front-panel switch for a possible future multi-channel upgrade. This would allow up to five simpler slave modules to be daisy-chained off CON8, all under your command via remote control! Pressing any of these buttons causes "C1" (meaning "Channel 1") to appear on the display – but has no other function at present (Fig.15, top right).

That's it – your new Remote Volume Control is ready for use. Sit back and enjoy the music. SC

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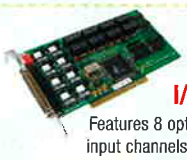

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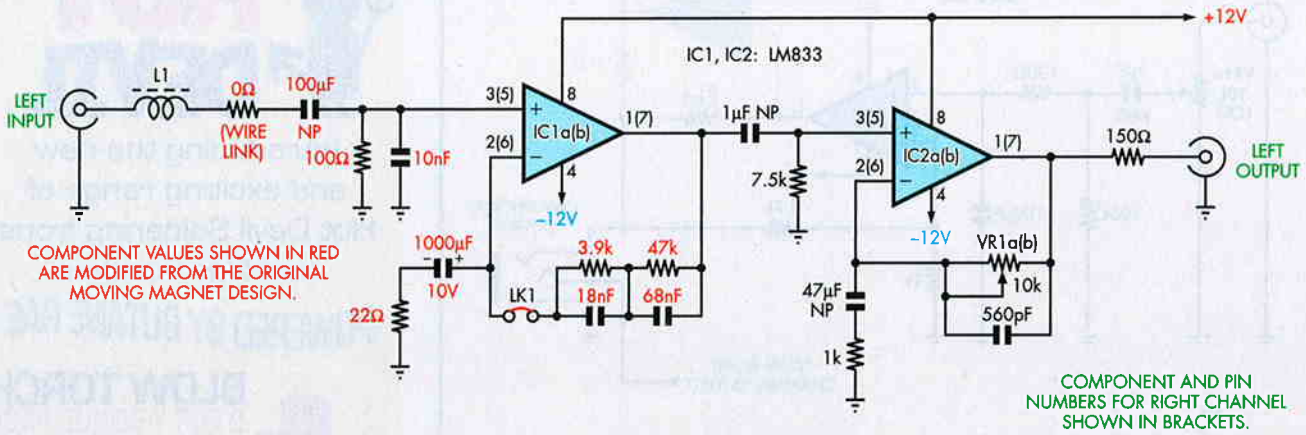

Preamplifier for moving coil magnetic cartridge

Most magnetic cartridges have a moving magnet that is attached to the stylus assembly. As the stylus tracks the record groove, the moving magnet induces corresponding audio signals in the coils of the cartridge and these are fed to the left and right channels of a stereo preamplifier providing RIAA frequency equalisation. So virtually all RIAA preamplifiers are designed to cater for "moving magnet" cartridges.

However, there is a less common type of magnetic cartridge, which is referred to as "moving coil". As the name suggests, this has very small coils attached to the stylus assembly and these are "bathed" in a fixed magnetic field.

Partly because the coil assembly in these cartridges is so small, their output signal voltage is much smaller than the signals from a moving magnet cartridge. However, some audiophiles prefer the sound quality of moving coil cartridges and hence there is demand for a suitable RIAA preamplifier, which must provide considerably more gain.

In fact, a number of readers have asked us to provide a variant of the Magnetic Cartridge Preamplifier featured in the August 2006 issue of SILICON CHIP. Fortunately, this is relatively easy to achieve because the preamp has two op amp stages to provide the required higher gain.

The modified circuit is shown above. In essence, all the changes have been applied to the first op amp stage (IC1a), leaving IC2a unchanged. The most significant change to IC1a involves a much lower input impedance and a lower impedance feedback network. The lower input impedance is required for matching with the low source impedance of a typical moving coil cartridge. The lower impedance input network also allows the op amp input circuit to "see" a much lower source impedance and thereby deliver a lower residual noise. The lower impedance feedback network has the same effect.

While the feedback values are changed, they still provide the same RIAA equalisation as our August 2006 design but about 10 times more gain. The remainder of the required gain is provided by op amp IC2a and this can be set to suit the particular cartridge by adjusting potentiometer VR1a. Identical circuit values are used in the second channel, involving IC1b & IC2b.

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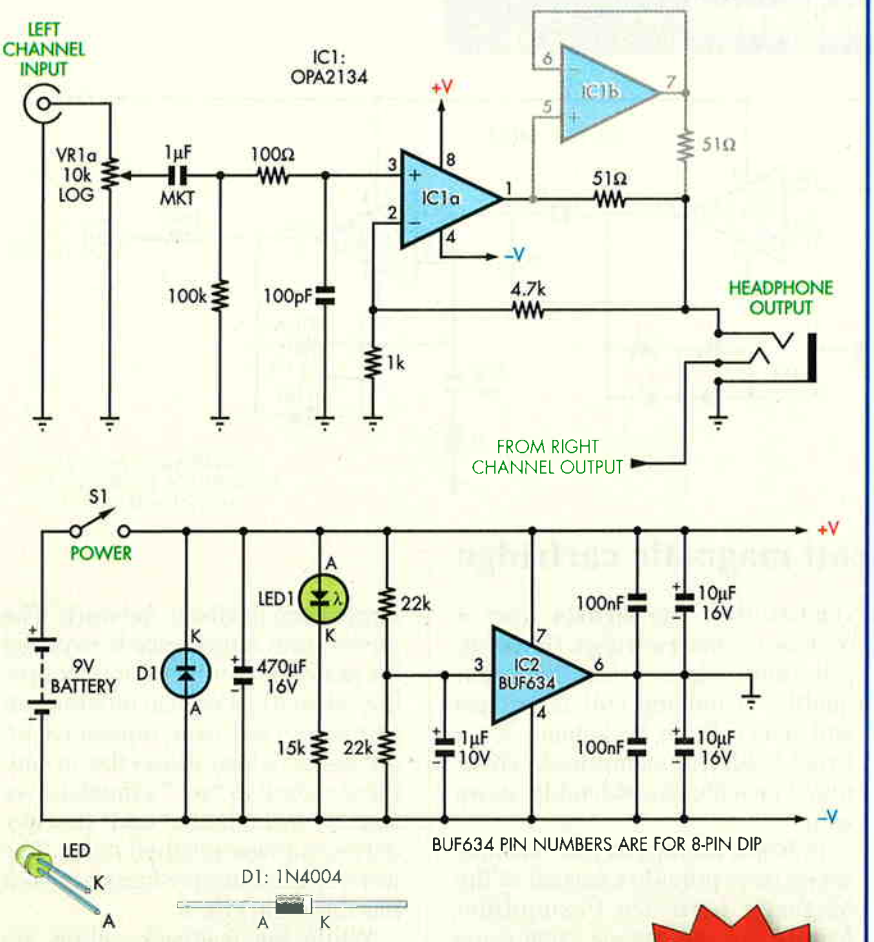


Portable headphone amplifier

Many portable CD/MP3 players exhibit high levels of distortion, even at reasonable power output levels. This low-distortion portable amplifier design can improve sound quality significantly by boosting signal levels to your favourite headphones. The idea originates from a simpler design by Cho Moy, described at **www.headwise.com**.

Each channel is driven by a high-performance OPA2134 op amp (IC1), configured as a non-inverting amplifier with a gain of about 15dB. Note that only the left channel is shown for clarity.

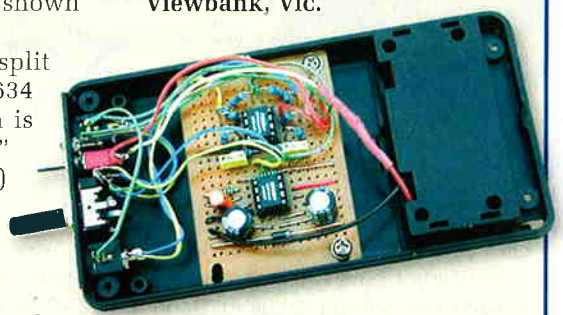
The 9V battery supply is split into ±4.5V rails by a BUF634 high-speed buffer IC, which is wired as a "virtual ground" generator. Its output (pin 6) drives the ground rail of the circuit to the mid-point of the battery supply, as seen on its input (pin 3).

Although the OPA2134 is only specified for driving loads down to 600Ω, it gives a good account of itself when driving the author's 60Ω Koss Sportapro headphones. The OPA2134PA and BUF634P are available from **www.farnellinone.com.au**, stock numbers 109-7574 & 483-1387, respectively.

Martyn Goodwin is this month's winner of a Peak Atlas Test Instrument

Editor's note: output power is easily doubled by adding a second op amp and 47Ω resistor in parallel with the existing op amp in each channel, as shown by the second device (IC1b) on the circuit. Obviously, this would reduce battery life, so it should only be added if necessary.

Martyn Goodwin,
Viewbank, Vic.



The prototype was constructed on Veroboard and housed in a handheld instrument case with an integral 9V battery compartment.

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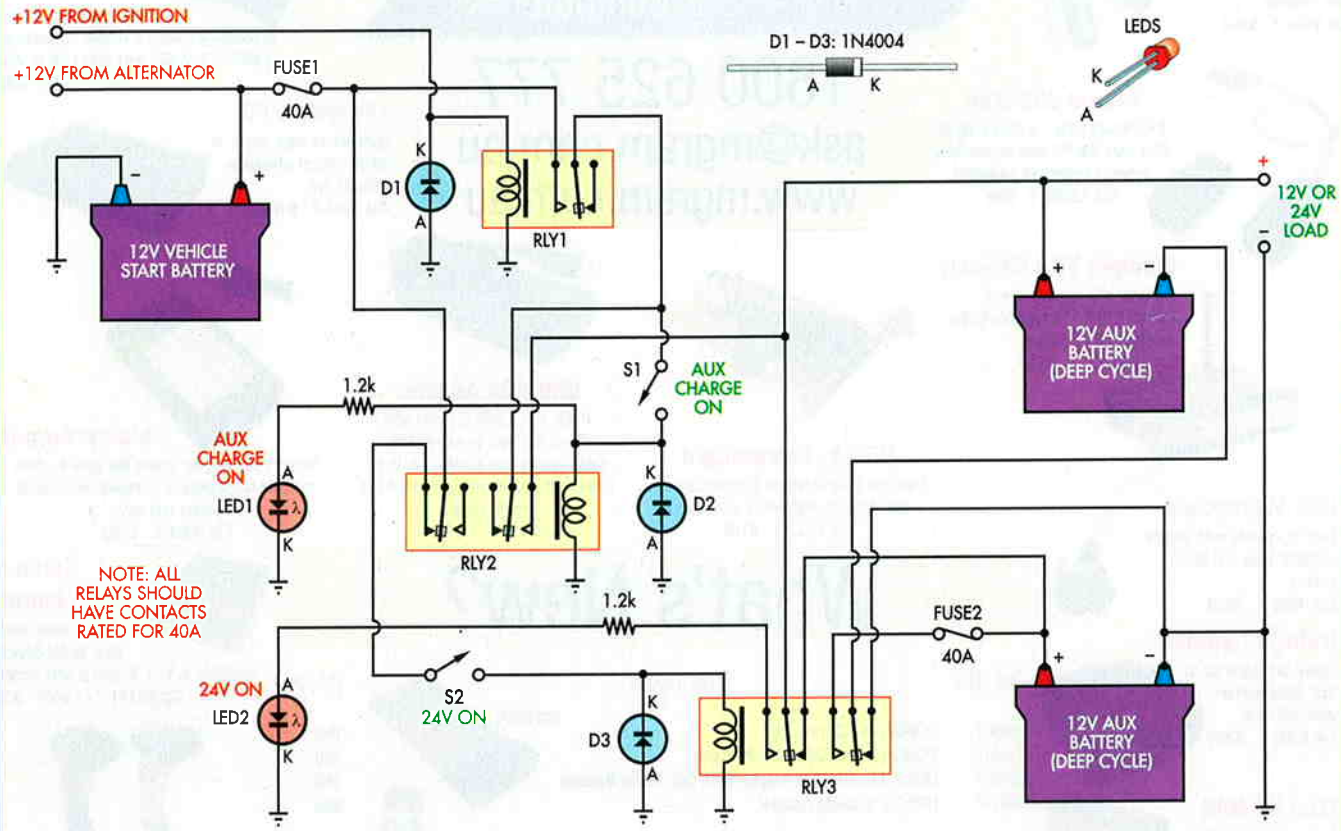
CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions from readers are welcome and will be paid for at standard rates.



12/24V auxiliary power system

This circuit provides a switchable 12V or 24V DC auxiliary power output using two 12V lead-acid batteries, three 40A automotive relays and two switches. It ensures that the vehicle battery is not drained when the ignition is off and automatically connects the batteries in parallel when charging, even if series connection (24V) is selected.

In more detail, when the 24V selection switch (S2) is open, the auxiliary batteries are connected in parallel via RLY3's normally closed (NC) contacts, supplying 12V to the load. Closing S2 actuates RLY3, connecting the batteries in series to provide 24V to the load instead.

Switch S1 is closed to charge the batteries from the vehicle's electrical system. Power to one end of this switch is supplied via the closed contacts of RLY1, which only pull in when the ignition is switched on. This eliminates potential drain from the vehicle battery. Once S1 is closed, power is removed from one end of S2, disabling RLY3 and ensuring that the batteries are always charged in parallel.

The main feed line to the circuit must be protected with a 40A automotive fuse (F1). A second fuse (F2) adds insurance against the failure of RLY3, which could theoretically see the terminals of the lower auxiliary battery shorted together.

Anton von Sierakowski, St. Arnaud, Vic. ($40)

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Type: 4 Way Barrier
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Rating: 20A @ 300V
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Width: 15mm

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MIN QTY 5

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2.5kΩ Wire Wound Pot.

Desc: Wire Wound Pot
Value: 2.5kΩ

$1.50

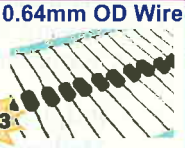
#34706

Leaded Ferrite Bead on 0.64mm OD Wire

Device: BDW3.5/6-3S4-L63
Function: Leaded Ferrite Bead
Size(mm): OD = 3.5 L = 6
Manuf: Ferroxcube

$0.03

#34861 MIN QTY 100



5VDC Coil 2A 30VDC-5A 125VAC Contact

Device: G5V-2 5VDC
Power Consumption: 500mW
Type: DPDT
Switching Current: 2A @ 30VDC
0.5A @ 125VAC
Switching Power: 60W
Coil Resistance: 50 Ohm

$0.60

#31240 MIN QTY 5

12VDC DPDT Switching 10A 240VAC PCB Relay

Device:JQX-13F
Contact: DPDT 10A 240VAC
10A 28VDC
Size(WDH mm): 27 x 21 x 35

$2.50

#34978

TO-220 Dual Case Heatsink

Desc.: TO-220 Dual Case Heatsink
Material: Aluminium,Blk Anodise.
Dim.: 46 x 46 x 31mm
Manuf.: AAVID THERMAL
Part No: 553044B00000

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100kHz 2.5A Switching Regulator

Device: LT1171CQ
Function: 100kHz 2.5A Switching Regulator
Package: DD-Pak
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#31199

30mcd @ 2mA Dark Blue (pk-100)

Type: SMD LED
Colour: Dark Blue
Lens: Water Clear
Lum: 30mcd @ 2mA
Manuf.: QT
*For Data See Web *

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#35299

60V 70A 35W N-Ch Power Mosfet

Device: 2SK3061
ID: 70A
Watts: 35W
Case: TO-220
** For Data See Web **

$1.00

NEC **#35301**

240AC Coil 5A Contact DPDT

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Contacts: DPDT 5A
Coil: 220VAC

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#29333 MIN QTY 5

2-11pF Varicap Diode

Device: BB521
Range: 2-11pF

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#26724 MIN QTY 20

4N28 Opto-Coupler

Device: 4N28
If: 60mA
Vceo: 30V
Viso: 7500pk
Package: DIP-6

$0.25

#34798 MIN QTY 10

2200µF 35V 105° Radial Electrol.Cap.

Type: Radial
Size (LxD mm): 31.5 x 16
Temp: 105°
Lead Spacing: 7.5mm
* Pre Cut Legs *
Manuf: SAMWHA

$0.20

#32797 MIN QTY 20

100nF 1600VDC MKP Capacitor

Value: 100nF (0.1uF)
Volts: 1600VDC
Type: MKP
Pin Spacing: 27.5mm
Size: 31.5 x 24.5 x14mm

$0.50

MIN QTY 5 **#34889**

15,000µF 16V 105° Snap-in

Type: Radial (snap-in)
Temp.: 105 DEG
Size: 25 x 35mm.

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Device: LM78L12ACZ
Rating: +12V
Package: TO-92

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8mm Red 7-Segment CA Display

Device: LSD3365-20
Type: Common Anode
Digit Size: 8mm
Size(HWD mm): 13 x 7.5 x 6.5
Manuf.: Ligitek

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MIN QTY 10

#34968

SMC PCB 50-Ohm RF Connector

Device:86 SMC-50-2-7/133
Imp:50ohm
Mounting:PCB ELBOW
Manuf:SUHNER

$0.50
MIN QTY 5

#26750

Hall Effect Micro Switch 20mA Sink

Device: 37XL11-03
Desc: Hall Effect Micro-Switch
Vs: 1.2VDC to 10VDC
Load: 20mA Sink
Manuf: HONEYWELL
Body Size: 28 x 16 x 10mm
* Data Sheet Available *

$2.00

#32925

30V 4A 20W P-CH SMD FET

Device: 2SJ325-Z-E1
Polarity: P-CH
Vds: 30V
Id: 4A
Pd: 20W
Package: D2-PAK

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#34969 MIN QTY 5

7.3728MHz Crystal Oscillator

Fq.(MHz): 7.3728MHz
Load Cap. 30pF
Package: 14-DIL

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#10250 MIN QTY 5

FKC2 WIMA Polycarbonate Cap.

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Manuf.: WIMA

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1kΩ 24-Turn Multiturn Trimpot.

Value: 1kΩ
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Power Rating. 0.5W
Voltage: 300V
Manuf: Spectrol 64Y

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Colour: Red

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#35354

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Temp: 105 Deg
Size: 10x20mm
Lead Spacing: 5mm
Supplied Tape & Reel

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ROCKBY ELECTRONICS

Odd/even day watering solution

Recent changes to garden watering laws have caused problems for some sprinkler controllers. The author's old controller could water on set days of the week or could be programmed to water every 2, 3 or 4 days, for example.

However, to suit Victoria's odd/even day watering cycle, it would need to be programmed for every 2nd, 4th or 6th day and then reset at the end of every month with an odd number of days.

New controllers that can handle this scenario without a reset at the end of the month are expensive (upwards of $250). The author settled on the reasonably priced Orbit 94946 (around $50), which can handle odd/even days and accounts for calendar months. Its only weak point is that it cannot water every odd 4th day, for example.

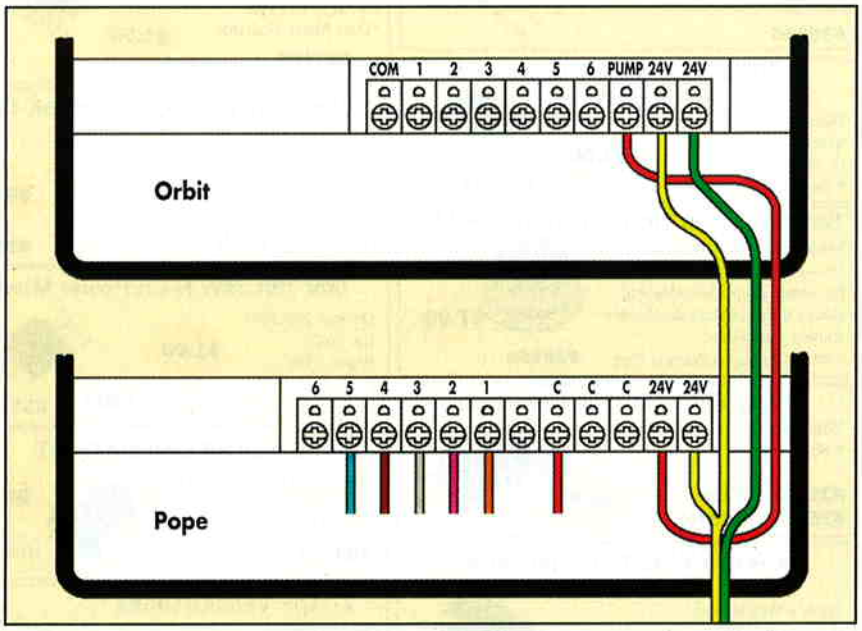


Fig.1: this diagram shows how the pump output from an Orbit sprinkler controller can be connected to the 24VAC input of a Pope controller to give greater programming versatility.

To get around this problem for minimum cost, the pump output from the Orbit controller can be connected to the 24VAC input of some older controllers – in this case, a Pope (see Fig.1). The non-switched 24VAC lead must be common to both units, as shown on the diagram. The sprinklers simply remain wired to the Pope controller.

In the author's setup, the Orbit controller is programmed to water every odd day and the Pope controller to water every Wednesday, Thursday, Saturday and Sunday. The end result sees the garden watered four times a fortnight, on odd days.

Many other watering combinations are possible using this basic scheme. For example, setting one controller to water on Monday, Thursday and Sunday will result in watering three odd days a fortnight.

Ralph Smith,
Melbourne, Vic. ($35)

Fun with flashing LEDs

Flashing LEDs can be used in a variety of ways, some of which may not be immediately obvious. This collection of circuits (Figs.1-11 on the facing page) should provide some ideas.

The basic flashing LED circuit is shown in Fig.1. Adding an ordinary LED in series (Fig.2) results in two flashing devices, while two in parallel (Fig.3) gives an "astable multivibrator" effect.

Want to flash more than one ordinary LED? Easy, just add any general-purpose, small-signal NPN transistor (Fig.4) to flash several at once. Replacing the resistor in the basic circuit with a piezo buzzer (Fig.5) provides a "beep-beep-beep" alarm is addition to the flashing LED – very attention getting!

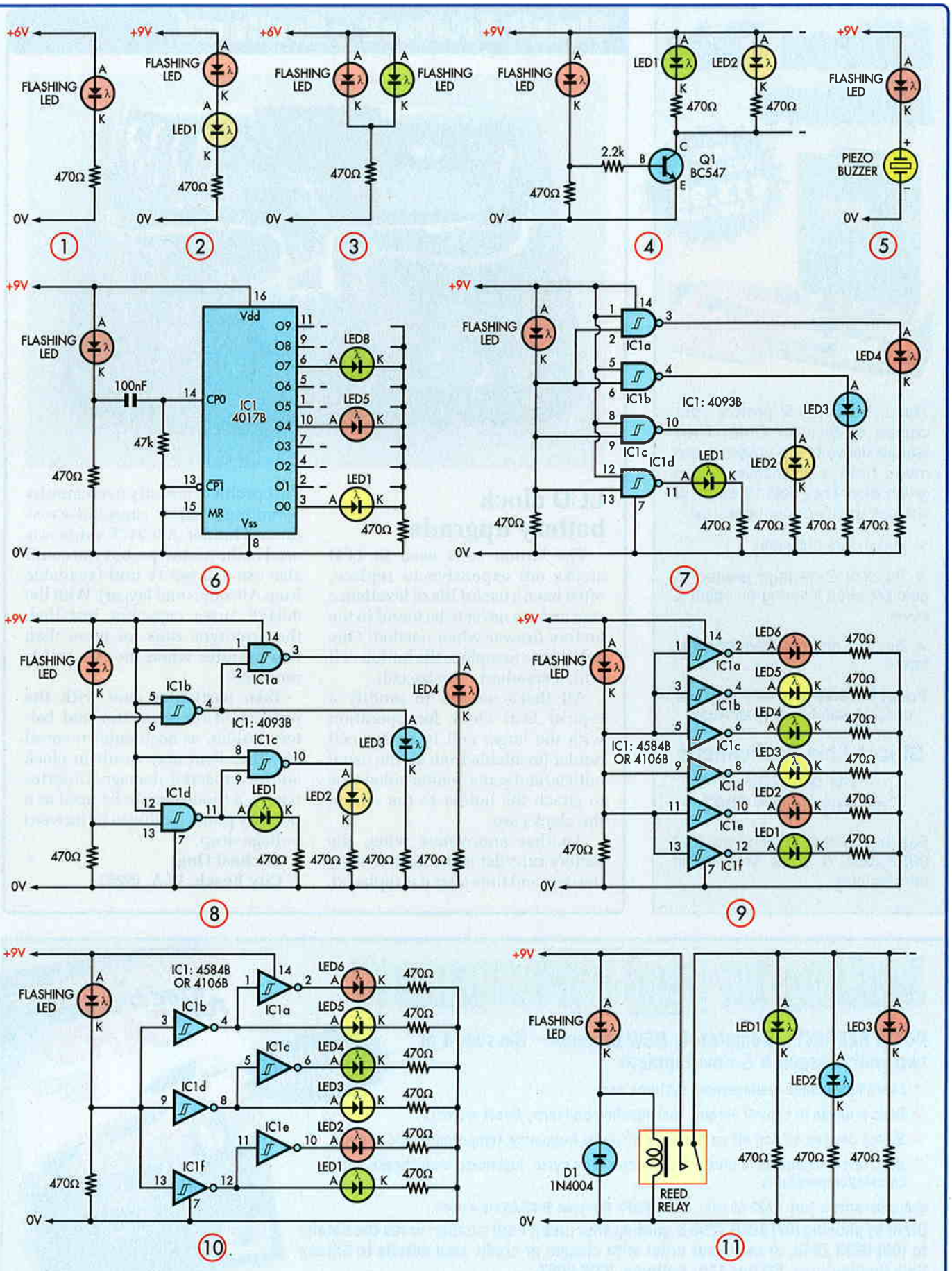
The basic circuit can also be used to drive one or more digital ICs, as shown in Fig.6. In this example, the 4017 decade counter's outputs can each drive a LED (or up to three in series) for an eye-catching display. One possible use might be to arrange the LEDs in an electronic die to achieve an ever-rolling die effect.

Schmitt trigger type CMOS gates can also be used with success. In Fig.7, four gates drive four ordinary LEDs. This is altered slightly in Fig.8, where the gates are paired to generate two multivibrator flashers. Up to six LEDs can be driven from a single 4584 or 4106 hex inverter package (Fig.9). Again, this can be rearranged as desired to drive alternate pairs (Fig.10).

If all you need is lots of LEDs flashing together, then replace the resistor in the basic circuit with a 500Ω reed relay (Jaycar SY-4030) – see Fig.11. This simple circuit will drive as many LEDs as the relay contacts can handle, and could work well as a bicycle tail-lamp.

The flashing LED used in all of these circuits came from Jaycar Electronics, Cat. ZD-0240.

A. J. Lowe,
Bardon, Qld. ($100)


+6V
FLASHING LED
470Ω
0V
1
+9V
FLASHING LED
LED1
470Ω
0V
2
+6V
FLASHING LED
FLASHING LED
470Ω
0V
3
+9V
FLASHING LED
LED1
LED2
470Ω
470Ω
2.2k
Q1
BC547
470Ω
0V
4
+9V
FLASHING LED
PIEZO BUZZER
0V
5
+9V
FLASHING LED
100nF
47k
470Ω
0V
IC1
4017B
Vdd
Vss
CP0
CP1
MR
O9
O8
O7
O6
O5
O4
O3
O2
O1
O0
LED8
LED5
LED1
470Ω
6
+9V
FLASHING LED
IC1a
IC1b
IC1c
IC1d
IC1: 4093B
LED4
LED3
LED2
LED1
470Ω
0V
7
+9V
FLASHING LED
IC1a
IC1b
IC1c
IC1d
IC1: 4093B
LED4
LED3
LED2
LED1
470Ω
0V
8
+9V
FLASHING LED
IC1: 4584B OR 4106B
IC1a
IC1b
IC1c
IC1d
IC1e
IC1f
LED6
LED5
LED4
LED3
LED2
LED1
470Ω
0V
9
+9V
FLASHING LED
IC1: 4584B OR 4106B
IC1a
IC1b
IC1c
IC1d
IC1e
IC1f
LED6
LED5
LED4
LED3
LED2
LED1
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LED1
LED2
LED3
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0V
11

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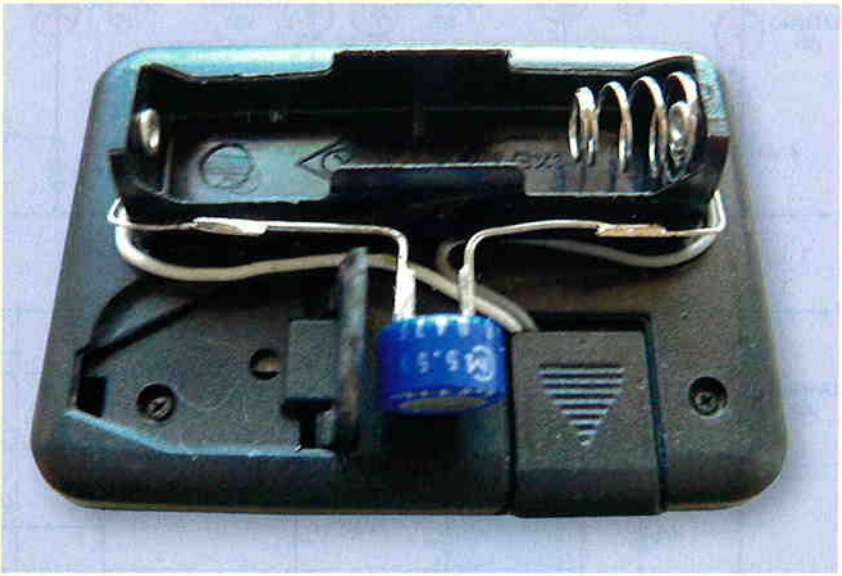
Circuit Notebook – Continued



LCD clock battery upgrade

The button cells used in LCD clocks are expensive to replace, often have a useful life of less than a year and are never to be found in the bottom drawer when needed! One solution is to replace the button cell with a standard AA-size cell.

All that's needed to modify a typical LCD clock for operation with the larger cell is an AA cell holder (available from all the usual outlets) and some double-sided tape to attach the holder to the rear of the clock case.

Another annoyance when the battery runs flat is the need to reset the date and time after it is replaced. This problem is easily overcome by mounting a "super" capacitor across the cell holder. A 0.047F value was used in the prototype, but you could also use a larger 1F unit (available from Altronics and Jaycar). With the 0.047F super capacitor installed, the prototype runs for more than two minutes when the AA cell is removed.

Take particular care with the polarity of the capacitor and battery holder, as accidental reversal of either item may result in clock and/or capacitor damage. Unfortunately, a diode cannot be used as a polarity protector due to its forward voltage drop.

Michael Ong,
City Beach, W.A. ($25)

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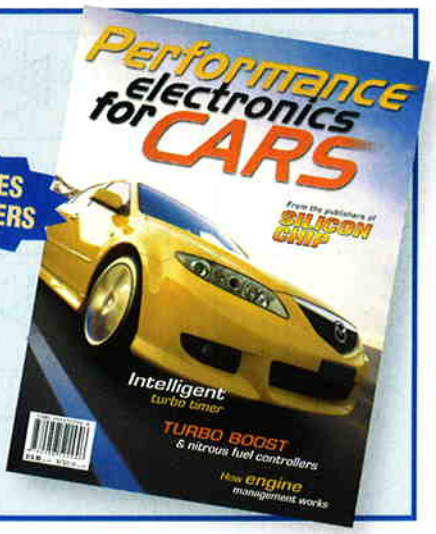
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PRODUCT SHOWCASE

Unique Aussie AM-FM Radio Broadcast Receivers

Three specialised high performance AM-FM radio broadcast receivers, designed and manufactured in Australia by Elan Audio, offer professional users significant advantages over traditional receivers.

Normal communication receivers are designed to receive speech only and have high gain, narrow bandwidth and a restricted audio-frequency response in order to pick up low-level radio signals with minimum interference and maximum intelligibility.

They usually suffer from high detector distortion and sideband clipping and generally do not sound particularly pleasant on speech, and quite bad on music.

The new Elan radio receivers are designed specifically to receive broadcast programs and have wide bandwidth input and IF circuitry with low-distortion detectors. All three receivers use the same "front end" receiver module developed by Elan Audio, which is based on a high performance car radio IC developed by Philips in Europe.

The **RMR-01 Monitor Receiver System** is designed for use by radio broadcasters as the primary high-quality studio off-air monitor receiver or as a general monitor receiver at transmitter sites. It allows a broadcaster to accurately judge transmission quality and to draw attention to potential problems.

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Finally, the **SMR-01 Scanning Receiver** is a "smart" or scanning monitor receiver intended for installation at a remote location where it can scan and monitor up to eight mixed AM or FM broadcast stations in its service area and report by fax if it has lost carrier or modulation.

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Cree XLamp XR-E LEDs now deliver up to 210 Lumens

Cree, Inc. a leader in LED lighting components and represented by Cutter Electronics announced that its award-winning XLamp XR-E LEDs are qualified for use in high-power applications of up to 1A.

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Cree claim that the XLamp XR-E is the best-performing power LED currently in production.

It is now qualified for extended performance in higher-power applications, such a portable lighting, where maximum light output is required.

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Along with their extensive range of school electronic, mechatronic and scientific supplies, Ballarat-based Wiltronics Research are now authorised resellers of all Picaxe products.

With the release of a brand new Scientific and Electronic Component wholesale catalog with in excess of 10,000 stocked lines (a 40% percent increase), coupled with automatic accounts to all government and educational facilities, Wiltronics remain committed to servicing the education market.

The 2007 Catalog available is due into schools in early March and is also available on request.

The full range of products is also on their website.

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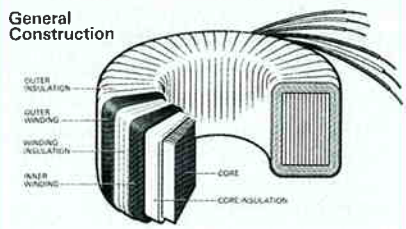

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OOPS! Yokogawa DMM price . . .

Yokogawa Australia were delighted with the response to the mini review of their superb 734/02 True RMS DMM (Product Showcase, February 2007).

Perhaps the response was a little too good?

The price quoted, $403+GST, was actually for a lower-spec model.

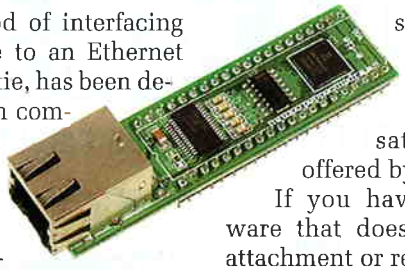
The correct price is $493+GST.

However, as a goodwill gesture, Yokogawa Australia are helping their sales agents, Trio Smartcal, honour the $403+GST price until the end of April 2007 for any reader who orders as a result of the review.

So (*nudge nudge, wink wink!*) if you want to get yourself arguably one of the best DMMs we have ever seen, at what amounts to about 20% saving on the normal (correct!) price, we suggest you run, not walk, to Trio Smartcal (find them via www.triosmartcal.com.au) before April 30.

Just make sure you tell them you saw the review in SILICON CHIP!

e-tie interfaces equipment to Ethernet networks



An efficient method of interfacing application hardware to an Ethernet network, called the e-tie, has been developed by Australian company, ipembedded.

Designed and manufactured in Australia, the e-tie module makes the TCP/IP software stack transparent to the customer and requires very little board space for implementation.

Basic hardware required to interface the e-tie is a 3.3V regulated supply (typically 160mA) and a Cat5 Ethernet cable. The e-tie can also run a dual input of 3.3V and 5.0V power supply to aid the interfacing of external microcontrollers.

The e-tie is shipped in a standard configuration as an http server with embedded web pages giving client access to digital inputs/outputs, serial inputs/outputs and analog to digital conversion readings. A software customisation service is also offered by ipembedded.

If you have application hardware that doesn't require Ethernet attachment or remote client firmware updates, the e-tie contains a bootloader programmed into the onboard PIC18LF4620 controller. The bootloader uses standard Intel Hex files, generated (for example) from the freely-available MPLAB program from Microchip. Retail price of the e-tie is $89.00 including GST.

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Website: www.ipembedded.com.au

Largest memory (4GB) on smallest (μSDHC) flash...

Driven by ever-increasing demands in mobile phones (especially), SanDisk has announced a 4GB microSD High Capacity (SDHC) card —the largest capacity of the world's smallest removable flash memory card. Release is planned for later in 2007.

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SDHC is the new designation for any SD or SD-based card that is larger than 2GB.

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Fluke Multifunction Electrical Tester Calibrator

Fluke Australia has released its new 5320A Multifunction Electrical Tester Calibrator, which calibrates many different types and models of electrical testers.

Traditionally, calibrating electrical testers has required a lot of equipment which in turn requires maintenance and training adding to time and cost.

The 5320A replaces resistors, decade boxes, and other custom calibration solutions with a single instrument. It also features precision high voltage, high current resistors to give technicians better test uncertainty ratios.

The Fluke 5320A Multifunction Electrical Tester Calibrator lets users verify and calibrate the following electrical testers: insulation resistance, continuity, earth resistance, hipot, loop/line impedance and ground bond, circuit breaker, leakage current, multifunction installation, portable appliance and medical electrical safety.

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The Spark That Chan

While its origins were in the 19th century, it is widely recognized that radio – and in particular broadcast radio – was one of the most significant developments of the 20th century.

by Kevin Poulter

The spark-gap transmitters which came into vogue after the turn of the century were capable of bridging continents but were limited to telegraphy only – Morse code. They spawned a lot of interest amongst experimenters and wireless enthusiasts but as a consumer item, they were a lame duck.

It took a lot more development to be able to transmit (and receive) voice and music. But over the next two decades such development did occur and radio broadcasting, as we know it today, became a reality.

The equipment to receive those broadcasts naturally followed. Thanks to some inspired and creative inventors and producers from the early 1920s onwards, we can now look back and see radios that are absolute works of art. The wiring is superb and the cases lovingly constructed to showcase the finest possession in the home.

Many of these treasures should be in museums but due to a lack of space and resources, plus the overwhelming demand for diversity in their collections, few radios are restored and displayed in public.

Fortunately, 25 years ago a group of radio enthusiasts created an organisation dedicated to saving and restoring many of these iconic centrepieces of the 20th century way of life. Now many collectors' homes display jaw-dropping collections of radio equipment and ephemera (posters, plans, circuits, advertisements and photographs).

The HRSA (or Historical Radio Society of Australia), was established by a small group of radio enthusiasts, motivated by Ray Kelly, in April 1982. Today, the HRSA has about 1000 members throughout Australia, with a number in overseas countries as well.

In the 1920s, 'coffin' radios were connected to external horn speakers like this Amplion. The first car audio systems even had horn speakers.

Not just domestic radios . . .

Australian mantel radios are the common interest, however the HRSA includes collectors of all types of receivers and even military radio equipment, television receivers, radiograms and more recently transistor radios. The most advanced members have 400 to 1,000 radios in their collections, so much of Australia's radio heritage is preserved.

What inspires people to share their love of radio and related information? It is the history, electronics innovation, development and amazing quality of workmanship in older radios. One of the greatest motivations is the thrill of finding and restoring a decrepit radio, or even rescuing one from the all too common imminent final journey to the tip and bringing it to as new condition.

Stories that chill the blood of collectors abound, like a huge collection of 78 RPM records in fine condition, offered to potential collectors but as the owner was too far away, there was no response. So the whole lot were burnt in a bonfire. Another company, not so long ago, had too many valves, so a skip was hired, filled with these hard-to-get parts and sent to the tip.

Most collectors especially like to have at least one nostalgic example of the radio make and model that bought the world to their kitchens or lounge-rooms throughout their childhood.

The development, enjoyment and subsequent collect-

ged the World

ing of radios, had its origins with the music-box – the first mechanical device that reproduced tunes at will. We are familiar with the 'barrel' cylinder music-box, however there were also disc versions. Some had different discs or cylinders with a choice of tunes, either fixed in the music-box, or removable, like CD players.

With this conceptual background, Edison made a monumental leap forward. He recorded sound onto materials such as wax, then reversed the process to replay it. From this earliest reproduction of sound via a needle there is a direct evolution to the sound, vision and computer discs we enjoy today.

Edison made two more vital discoveries in radio's early history: the carbon microphone and the diode valve. The difficulty with the diode was that he couldn't think of an immediate application, so it was left to others to develop many years later.

The first radio "broadcasts"

Once the first sparks were sent through the air as Morse Code (which, incidentally, occurred in Italy in 1895), radio had begun. A host of inventors including Marconi made valuable contributions, until the public broadcasting of voice and music around 1920.

Most radio broadcasts of the day were ad-hoc affairs by amateur operators using their own "home brew" gear. There were no such things as schedules or programming!

Part of the reason was that there was virtually no receiving equipment, at least not in the hands of the general public.

The first public radio broadcasting station is usually credited to Dutch amateur Hanzo Idzarda, who commenced transmissions from his station PCGG in The Hague on 6 November, 1919.

The BBC started regular broadcasts on station 2MT from London on 14 November, 1922 (even though it had been transmitting for some months before) and Australia joined the radio revolution when radio station 2SB began public broadcasting on 23 November 1923.

2SB, owned by Broadcasters (Sydney) Ltd, had been in a race with rivals Farmer and Company, who promised in August 1923 to start broadcasting from their station, 2FC, on November 15. 2FC didn't make their deadline and started on December 5th. (2SB later became 2BL and both 2FC and 2BL were later absorbed into the Australian Broadcasting Commission, or ABC).

Some suggest 2SB wasn't the first station to "broadcast" in Australia. It was the first to "officially" broadcast regular programming but the honour of first in Australia belongs to renowned radio pioneer, Charles Dansie Maclurcan, whose station 2CM in Agnes St, Strathfield started in 1921 with a 90-minute concert every Sunday night. Maclurcan in fact had the first licence to broadcast in Australia.

And if you're looking for a question to stump even the most ardent trivia buffs, the first piece of music "officially" broadcast in Australia (on 2SB) was "The Swan" (Le Cygne), from Saint Saens' "Carnival of the Animals" (Carnaval des Animaux).

Do it yourself!

Soon private and commercial constructors were making superb valve radio receivers

The first bakelite radio, the AWA Radiola C87, the pride of the AWA fleet, is one of the most sought-after radios amongst Australian collectors. Bakelite radios are sometimes discovered damaged, though most not as severely as this. HRSA member Ray Hosking restored this AWA C87 to like new.

and crystal sets, aided by a host of magazines on the subject. Reception was regenerative or superheterodyne (superhet). True crystal sets, now highly sought after by collectors, were built into wooden bases or ornate boxes. My grandfather built a crystal set with twin headphones, so he and his wife could both listen to radio in bed at night.

The valve receivers in the 1920s were in 'bread-box' shape, with a lid for access to the electronics and valve replacement. Collectors irreverently nickname radios of this era 'coffin radios', due to their outline. Wood was the most common cabinet material, though a few were in metal, with the brand embossed on the case or added as an embossed metal plaque.

By 1930, two new styles appeared, 'Cathedral' and 'Console'. The Cathedral mantel and table radios had a curved peak, reminiscent of Gothic-style archways and windows, finished in wood or B akelite while the Console was a big-sound, floor-standing, waist-height radio.

The Console benefited from its spaciousness, with room for a large speaker and the huge case acting as a superior baffle. The Console's sound was big, with rich tones.

Both types became immensely popular as manufacturers competed for the finest decorative furniture appearance, at an affordable price. Householders took great pride in displaying them as the feature of their homes.

The Astor Mickey mantel radio was the first Bakelite Mickey, with the name 'Mickey Mouse' on the front. After losing a trademark infringement battle with Disney, the next model was licenced and had a Mickey on the dial and in a colour transfer on the rear.
(Below left): once Astor could legally use the name and image of Mickey Mouse, the character featured prominently on their radio and advertising, such as in this advertisement from the December 1933 edition of Wireless Weekly.

THE CRAZE THAT'S SWEEPING THE WORLD PRESENTED TO AUSTRALIA
for the first time
2BL SYDNEY
4QG BRISBANE
3LO MELBOURNE
5CL ADELAIDE
• SMALLER THAN A MANTEL CLOCK
• WEIGHS SAME AS A JUNIOR MOVIE CAMERA
• GUARANTEED SAME POWER AS FULL-SIZE SET
• GUARANTEED SAME RANGE AS FULL-SIZE SET
A handful of Radio marvel . . . Take it with you anywhere . . . Just plug into nearest light socket . . . gives perfect inter-state reception . . . No aerial, no earth required . . .
(ACTUAL PHOTOGRAPH)
ASTOR MICKEY MOUSE
5 VALVE SUPERHETERODYNE £12/12
Much smaller than any other receiver on the market; measuring only 10¼ in. long by 7 in. high by 5¼ in. wide, entire receiver can easily be concealed behind an ordinary pad of letter paper.
Interstate Reception Guaranteed—Outstanding performance achieved by new 2-in-one Double purpose valves. Logs 30 to 40 stations.
Automatic Volume Control reduces fading and stops blasting.
Full-powered Superheterodyne with patented static reducing circuit operates special Jensen Dynamic Speaker, definitely preserving power and tone of large receivers despite incredible compactness. With full 12 months' guarantee. Amazing New Low Price, £12/12/-, or Terms to suit your convenience. Ask your nearest Astor Dealer
TAKE HIM
TO BED
TO THE KITCHEN
TO THE NURSERY
ON HOLIDAYS
TO THE PARTY
New South Wales Distributors: SMITH, SON and REES LTD., Wentworth Avenue, Sydney.
Wireless Weekly, December 15, 1933

In the early 30s, a plastic-like material called Bakelite revolutionised the mass-production of radios (and indeed many other products, diverse as wall power/light switches, pens and even women's jewellery such as bangles). Produced under immense pressure, Bakelite could be manufactured into cases with thousands of identical shapes, with many different colours. It was very durable and simply wiped clean.

Australia's first Bakelite set, the C87 made by Amalgamated Wireless of Australia (AWA), was made in 1932. Soon manufacturers found they could add flecks or veins of colour, resembling marble, making radios that are now highly sought-after. And radio electronics progressed beyond regenerative receivers to top-performing superhet designs.

Mains power was not supplied in many towns and farms, so battery sets were very common. People in the bush demanded high performance so they could hear distant stations clearly, so Australian radios compared well with the best in the world.

During the Cathedral era in the 1930s, Astor radio introduced the Mickey Mouse radio, a small mantel with big radio performance. Disney objected to the use of his character's name and Astor chairman Sir Arthur Warner fought his request for a small royalty through the courts, until Disney won.

Once Astor was obliged to pay royalties, they took full advantage of the rights and produced a revised Mickey Mouse radio, with a cartoon Mickey on the front and the rear and in advertising. This radio had a very long product life, with a version still being sold in 1943.

Older radios should not be turned on, 'to see if they work', as capacitors and other components short or open circuit with age. These capacitors have obvious leakage. Restorers replace capacitors with modern types. To show future generations how the original radio looked, the chassis is photographed before repairs. The replaced capacitors are then stored in a plastic bag near the radio. The ultimate restoration involves cleaning out the inside of the original capacitor, leaving a hollow exterior shell. A 21st century capacitor is placed inside and when re-installed in the radio, it's impossible to tell from the original.

When Astor decided to drop the Mickey Mouse drawings and not pay royalties, a new plastic-cased radio was still cheekily called 'Astor Mickey'. Both Astor Mickey radio series had longevity, selling for about a decade. Imagine the tooling and production savings. Today an electronic product's sales life can be less than a year. Certainly this is true of car audio manufacturers who produce one or two model range updates every 12 to 18 months.

AWA, led by Sir Ernest Fisk, designed technologically advanced radios. The AWA C87 bakelite set, previously mentioned, is now one of the most sought-after and valuable radios in collections today.

By the mid-thirties, AWA designed a large mantel radio said by some to be modelled after the AWA building headquarters in Sydney. Due to the skyscraper like appearance, the radio has the moniker 'Empire State', after the famous classic American skyscraper. The style remained in a number of different variations for many years.

The small Bakelite mantel radio became the most affordable and purchased radio in the 1940s, with most moving from the big radio in the lounge room to a more compact unit in the kitchen. After all, the kitchen is where most people had the time to listen.

Danger, Will Robinson, Danger!

While some early battery-operated radios are still occasionally discovered, nearly all collectable radios these days are mains-operated. And they are obviously old, so the HRSA promotes safety as paramount.

For example, in some models of the Empire State radio, heat-insulating material was placed between a valve and IF (intermediate frequency) transformer, to avoid the transformer drifting off tuning as the radio heats up. The insulating material? Asbestos!

Don't blame the manufacturer – in its day, asbestos was considered a wonder insulator and nobody knew of any harmful effects. Today we know that you should not break up or even touch this material without protection. Some authorities even maintain the slightest inhalation is highly dangerous.

Despite this, left alone, asbestos poses little health risk, so most states still allow sales of collectable appliances with this material.

Incidentally, we have also seen asbestos in radiograms from much later times – in the 1950s – so take care.

Other hazards include old rubber-covered wiring, either under the chassis or in the mains cord. Unfortunately, the rubber perishes over the years, often leaving bare copper wire exposed. As a matter of course, old mains cords should be replaced. If you want to maintain at least a look of authenticity, woven-cloth-covered mains cable (as used for electric irons) is a reasonable substitute. HRSA members use an authentic-looking brown cotton-covered cable.

There are other electrical safety considerations too, perhaps not directly associated with the radio but with the home it lives in!

Some pre-50s homes, for example, have power points with Active/Neutral transposition, as they were wired before modern electrical rules.

This means you can turn the mains switch off at the wall and the radio will go off. But live (Active) wires still go to the radio. Touching this exposed Active and the chassis or other earth, will be a shocking experience!

Using a cheap neon screwdriver, the author found two out of four power points in one 1950s schoolroom dangerously reverse-polarity!

So it's vital to check your power points. In addition, the use of an earth leakage lead or socket (RCD) is highly advised. Regardless, the plug should be removed from the wall before attempting repairs, just in case.

Another killer – literally – can be those old-style "mir-

HRSA member and 32V "fanatic" Greg Lamey adjusts a 32V vibrator in his radio shed at Cuddlee Creek in the Adelaide hills. Near the shed is a 32V wind-powered generator restored with parts scoured from the Nullabor Plain and other remote parts of South Australia. It supplies a large bank of ex-telephone exchange batteries with two 1930 Ruston-Hornsby diesels for backup.

It's not all valves and high voltages : early model transistor radios – such as this AWA Radiola Transistor Seven – are also lovingly restored by HRSA members

ror image" double adaptors. These were outlawed at least 20 years ago but its amazing how many still turn up. They seemed like a good idea at the time but by design, one of the two outlets has Active and Neutral transposed.

Of course, live-chassis radios are one of the biggest dangers to the inexperienced. The AC/DC radios that operated directly from a DC supply in some towns should be approached with caution. They don't have a power transformer, so depending on the polarity of the mains power point, the chassis can be live.

Even with a fully closed set, a knob can still fall off, exposing metal. Or even more unexpected, the grub-screw holding the knob may be long enough to touch.

If the mains cord is frayed, don't shorten it, as it may be a resistance wire, to reduce the input voltage. An isolating transformer is recommended but even this does not result in a 100% safe radio.

Most HRSA collectors are from an electronics background, or receive assistance from members with the necessary expertise. At the Society's regular auctions the HRSA complies with electrical safety regulatory requirements, including all equipment for sale displaying a safety notice (further details in the web references).

eBay has changed the buying and selling of radios. Some collectors find greater access to interesting items. If you are tempted to give it a go, ask friends about safety and security issues. Be aware of statements like 'not working – needs a valve – should be easy to fix'. Translation – I switched it on and smoke came out, so I'll get rid of it.

Or 'Valve, New in Box'. This is sometimes described as 'NOS' (New Old Stock). While there are amazing numbers of never-used old valves still in existence, it's quite common to find a faulty valve in a nice box.

The reason? 'Valve jockeying', or trying new valves first before proper circuit analysis. This often achieved results, albeit temporary. Without proper circuit repairs, to repair the real fault, many new valves degenerated to the state of the replaced one.

Due to the cost and inconvenience of securing a wide range of valves – and the chance valve replacement was not the solution – technicians and hobbyists changed each valve, placing the old one in the box. Unless the valve was in a very poor state, most were kept for valve-jockeying tests. If there was some improvement, then a new valve was purchased.

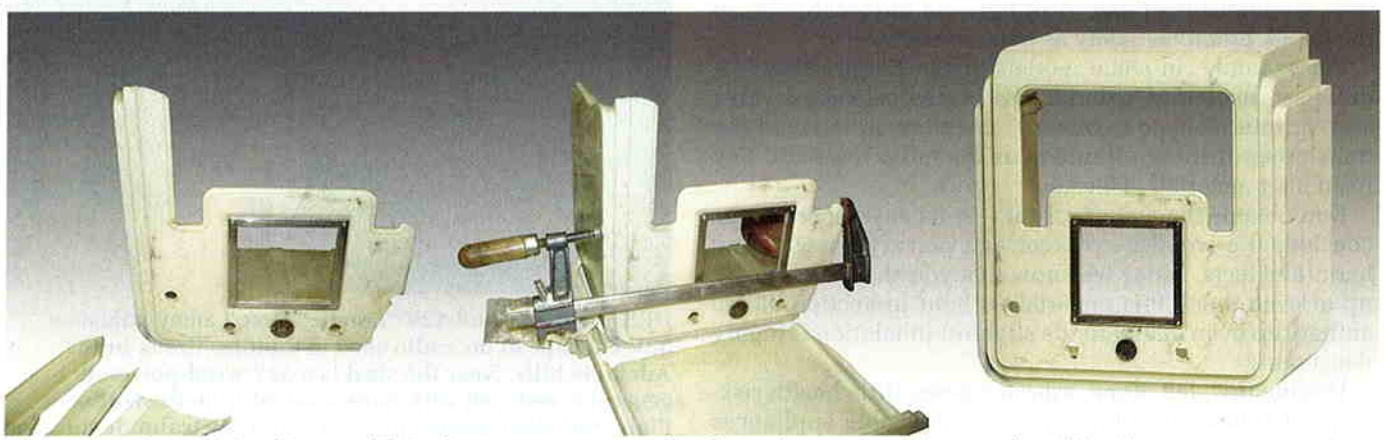
Don't plug it in and turn it on . . .

A final safety tip: never turn on an old radio 'to see if it works'. This is not only dangerous for the operator but can destroy a classic radio in an instant, reducing its value and restorability to near zero in one unwise move.

Old parts such as capacitors (they were originally called condensers), transformers and resistors may have a short, so the radio 'fries'. Instead of just turning on an old radio and standing back, check it over first, physically and electrically. Power transformers and the like are much harder to source than new, reliable, capacitors.

Many advocate replacement of all the electrolytic and other suspect (especially paper) capacitors, as if they are not faulty now, they soon will be. Test the chassis for shorts and if possible, do a "Megger" test. For the inexperienced, ask someone who knows old radios to do this for you.

For more information on restoring early sets, SILICON



The restoration of this white 'marbleised' AWA case passes the closest inspection. The severity of the damage – even greater than the progress photograph on the left – would normally mean it would be thrown out, but sets like this are quite rare.

A beautifully restored "Peter Pan" radio, model BKJ (1946-7), manufactured by Eclipse Radio, Melbourne.

CHIP has a "Vintage Radio" column in every issue, written by HRSA member Rodney Champness.

50s optimism

After the war, the world surged with new optimism, producing inventive, productive and colourful products. A major development was plastic, with all its colours and ease of production. Two radios came to the forefront – plastic mantels and radiograms (record players with radios in a beautiful wood console).

Colour was everywhere in the kitchen and radios followed suit, with hardly a brown radio in sight – the only brown or other warm tones remaining were in the timber finishes of radiograms and TV sets, relegated to the loungeroom. Radiograms often have high-performance multi-band receivers but few are collected, due to their size.

TVs often end up at the tip too or sadly are stripped and made into fish tanks. That was all the rage a decade or so ago!

By the early 60s, transistor radios surged in popularity. Today, their prices are generally lower than the older valve models and the designs appeal to younger members, so there are collectors addicted to these battery portables.

Many members of the HRSA mostly specialise in a genre or era – for example, military radios. Many have extraordinary knowledge and information on their speciality. This is shared and traded between members, one of the great advantages of the HRSA.

There are also members that offer speciality services, such as repairs to components like speakers, wood or bakelite. Ray Hosking is the master of bakelite repairs and his work is shown here. On completion, his repairs are completely invisible (he *can* make a silk purse from a sow's ear!).

Bakelite is a strong material but eventually becomes more fragile. So the common practice of picking up sets by holding their bakelite top is not advisable – always carry radios held from the base.

SILICON CHIP is a keen supporter of the HRSA's goals and this is highly appreciated by all members, especially as many read SILICON CHIP. In fact one of the winners of the inaugural SILICON CHIP Excellence in Education Technology award, Lauren Capel, restored a radio and built a power supply, plus MP3 player and mini AM transmitter, drawing on information and advice from HRSA members.

The Society's activities include auctions, a quarterly magazine with information, circuits and trading pages, meetings around Australia, technical and historic talks, restoration workshops, construction projects, technical library, circuit service, participation in shows and events and a valve/component bank, all for just $27 a year.

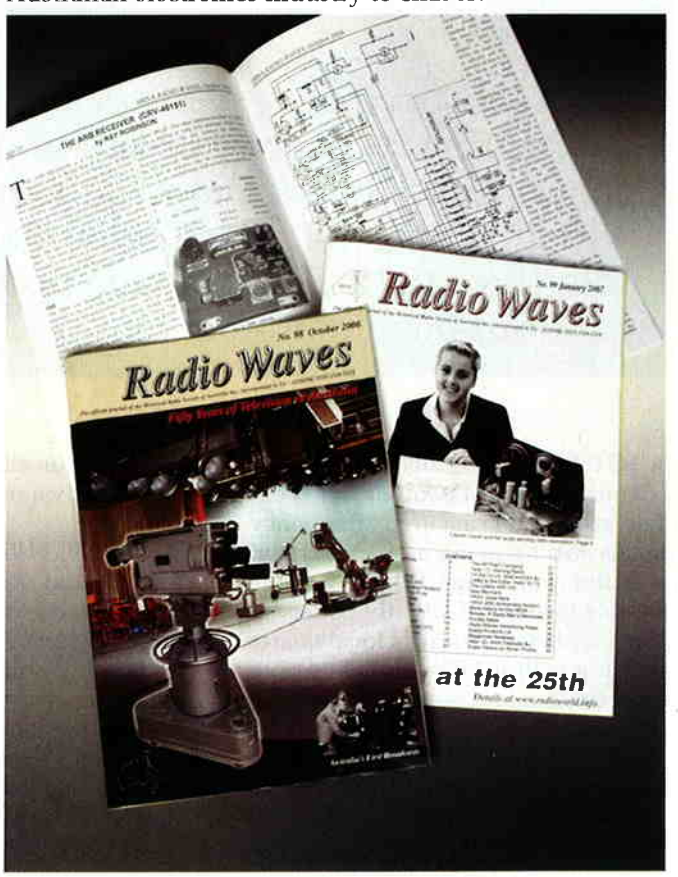
HRSA's big show!

To mark the 25th anniversary of the HRSA, the organisation is staging a huge national event in Melbourne next month (April). Located in the vast Holmesglen Conference Centre, cnr Batesford & Warrigal Rds, Chadstone, there will be displays and activities for members and the public.

Highlights will include a radio display, stunning in quality and quantity, an old radio store, a battery store, continuous radio shows from a large room full of consoles, working portables on parade, posters, images of Australian radios and production, giant auction, swap-meet, guest speakers, radio films, valuations and much more.

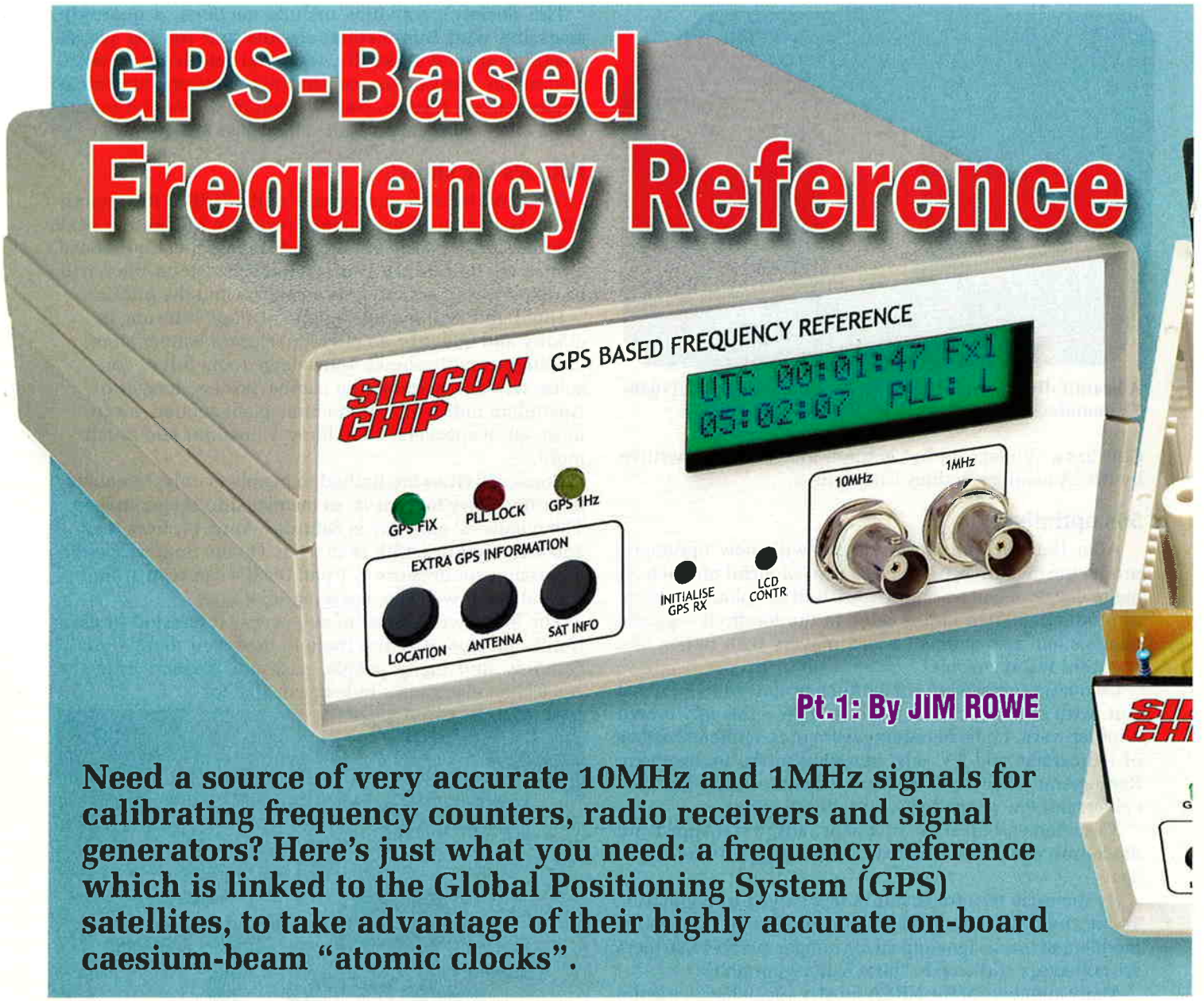
Some activities are limited to members only. Members have free entry both days, so membership is encouraged. The members' only day is Saturday April 14, from 9 am and Sunday April 15th from 9 am. On the Sunday, public admission commences at 1 pm. Details can seen at the special event web site, **www.ozradios.com**

The event will appeal to any people interested in electronics or vintage radio. Hope to meet you there – you'll certainly find many people, past and present, from the Australian electronics industry to chat to. SC



The HRSA magazine Radio Waves, is published quarterly, edited by HRSA life-member, Bill Smith. Features include radio collections, events, radio restorations, auctions, sale of new or used parts and historic radio stories.

GPS-Based Frequency Reference



Pt.1: By JIM ROWE

Need a source of very accurate 10MHz and 1MHz signals for calibrating frequency counters, radio receivers and signal generators? Here's just what you need: a frequency reference which is linked to the Global Positioning System (GPS) satellites, to take advantage of their highly accurate on-board caesium-beam "atomic clocks".

NOT TOO MANY decades ago, the only way most people could generate reasonably accurate frequency signals was by using a quartz crystal oscillator. Following this, it became possible to achieve slightly better accuracy by heterodyning a local quartz oscillator with an HF radio signal from one of the standard frequency and time stations, such as WWV in the USA or VNG in Australia.

By about 1980, even higher accuracy could be obtained by locking a local quartz crystal oscillator with the horizontal sync signals from one of the national TV networks. That's because the networks used a master timing clock that was locked to an "atomic clock" based on either a caesium beam or rubidium vapour oscillator.

The GPS system

The Global Positioning System (GPS) became operational around 1990 and is run by the US Department of Defense. By using this system as a reference, it's possible to generate reference frequencies with extremely high accuracy – even better than using the previously listed methods.

That's because each of the 22-odd GPS satellites orbiting the Earth has two caesium beam atomic clocks on board. These are necessary to generate the very accurate frequency and time signals needed for accurate positioning. And since there are always at least four GPS satellites "in view" at any time from any point on the Earth, this means that there's always access to an "ensemble" of about eight caesium beam clocks to serve as a frequency reference – provided you have the right GPS receiving equipment, that is.

The only problem was that until a couple of years ago, GPS receivers were quite expensive. However, costs have fallen quite dramatically since then – so much so that handheld and mobile GPS navigators are now everyday consumer items. In fact, low-end navigators with colour LCD screens are now down to around $400. Small wonder they're becoming so popular!

The unit is housed in a plastic case and provides accurate 10MHz and 1MHz reference frequencies via front-panel BNC sockets. A range of data can also be displayed on the LCD, including UTC time and date and the receiving antenna's latitude, longitude and height above mean sea level (see panel).

As you might expect, inside each of these navigators is a complete GPS receiver module. However you don't have to buy a navigator to get the receiver module, because they are also available separately for use in other equipment. And that's just what we've done here – use one of these "bare bones" receiver modules as the heart of this project.

Garmin GPS 15L

The GPS module we chose to use is a Garmin GPS 15L, which is available from local distributors for about $130. It's quite a tiny device, measuring just 46 x 36 x 8.5mm and weighing in at only 14.1g. But don't let the size fool you because there's a lot packed into it. Inside, there's a complete 12-channel GPS receiver which can track and use up to 12 GPS satellites at once. And it can provide a swag of GPS-derived time, date, position and satellite status information in serial RS-232C text form – updated each second, no less.

It also provides a one-pulse-per-second (1PPS) output, where the leading edges of the pulses are very accurately locked to the UTC-derived GPS timing system. It's these pulses that we mainly use in the reference, to control the frequency of a local 10MHz crystal oscillator.

For best performance, you do need to feed the Garmin GPS 15L receiver with good-quality signals, though. This means mounting a small active GPS antenna in a clear area outside, as high as possible so that it can get an unobstructed "view" of the sky in order to receive the satellite signals.

The antenna is connected to the antenna input of the receiver using a suitable length of good quality 50Ω coaxial cable. This delivers the amplified 1.575GHz GPS signals to the receiver and also feeds the active antenna with DC power (provided by the receiver).

In our case, we chose a Garmin GA 29F flush-mount active antenna, which costs about $90. This was mounted on a plastic junction box and fitted to the top of the author's TV antenna mast (see photo). We also tested a D-3856 antenna made by Australian firm RF Industries, which also worked well. This unit is available from Dick Smith Electronics and Tandy outlets for just $69.

Taken together, the GPS receiver module and an active antenna will set you back about $200. The rest of the parts will probably be around the $150 mark, so you should be able to build the whole shebang for about $350. This is just a fraction of the price you'll pay for a commercially available GPS-based frequency reference.

How it works

To get a handle on how it all works, refer now to the block dia-gram of Fig.1. Basically, the frequency of the 10MHz crystal oscillator (top, right of Fig.1) is controlled using a phase-locked loop (PLL). This PLL, in turn, uses the very accurate 1Hz pulses from the GPS receiver module as its reference. However, the PLL configuration is a bit more complicated than normal, so let's look at this in greater detail.

Basically, the reason for the added complexity is that it isn't easy to control a 10MHz crystal oscillator using a reference frequency as low as 1Hz – at least not using a standard PLL. That's because with a standard PLL configuration, the oscillator frequency must be divided by 10,000,000 (to get 1Hz), to be compared with the reference frequency in the phase comparator. However, such a high division factor involves a relatively long time delay and this adversely affects the error correction feedback, making it very

A small active GPS antenna is necessary to receive the GPS signals. The author used a Garmin GA 29F antenna. This was mounted on a plastic junction box and fitted to the top of an existing TV antenna mast.

difficult to stabilise the PLL.

To get around this problem, we divide the 10MHz oscillator output by a much smaller factor – only 200 times in fact. This is done in separate divide-by-10 and divide-by-20 stages using synchronous divider ICs, so that we end up with 50kHz pulses which have the timing of their leading edges (L-H transitions) very closely synchronised with the leading edges of every 200th pulse from the 10MHz oscillator.

This means we have effectively transferred the phase of the 10MHz oscillator signal (averaged over 20µs) to the 50kHz signal at the output of the divide-by-20 divider. And it's the phase of this signal which we feed into the second input of the phase comparator, where it's compared with the leading edges of the 1Hz pulses from the GPS receiver module.

The phase comparator does exactly what its name implies – it compares the leading edge of each 1Hz GPS pulse with the 50kHz pulse nearest to it and generates a "phase error" pulse, the width of which is directly equivalent to the timing difference. One of these phase error pulses is produced at the start of each 1Hz GPS pulse and they can vary in width from zero (when the two signals are exactly in step) up to a theoretical maximum of 20µs (when the two signals are one period of 50kHz out of step).

In practice, we use the PLL's feedback loop to maintain a fixed phase error of about 10µs (ie, halfway in the range). This gives the PLL the widest possible control range, to ensure reliable locking of the 10MHz crystal oscillator.

Deriving the feedback voltage

OK, so how do we use the varying phase error pulses from the comparator to produce an error correction feedback voltage for the 10MHz oscillator? Well, what we do is use the error pulses to control an AND gate which then passes pulses from a second crystal oscillator (running at about 10MHz) to an 8-bit binary counter. So as the error pulse width varies, it allows a varying number of these "about-10MHz" pulses to reach the counter.

For example, if the phase error pulses are 8.0µs wide, 80 pulses will be gated through to the counter. And if the pulses are 11µs wide, 110 pulses will be fed through, and so on. So at the start of each 1Hz GPS pulse, a burst of "about-10MHz" pulses will be fed to the counter, the number of pulses in the burst being directly proportional to the phase error.

The counter is actually reset at the end of each 1Hz GPS pulse, so it counts up from zero each time. At the output of the counter we also have an 8-bit latch and a simple digital-to-analog converter (DAC) using a resistor ladder network. After the end of each phase error pulse, the latest error-proportional pulse count is transferred into the latch, replacing the previous count.

As a result, the output of the DAC is a DC voltage which varies in level each second, according to the phase error. So the phase error has been converted into a varying DC error voltage.

Get the idea? When there's a fixed phase error of say 10µs, the counter will have a count of 100 each time and the DAC will have an output voltage of almost exactly 1.953V. This voltage will vary up or down in steps of 19.53mV, as the phase error pulses vary in width and the number of "about-10MHz" pulses fed to the counter varies up or down. Each of the "about-10MHz" pulses fed to the counter corresponds to a phase error step of close to 100ns, so our phase error-to-DC error voltage conversion circuit has a conversion gain of 19.53mV/100ns or just under 2mV for every 10ns change in phase error.

Why two 10MHz oscillators?

By now, you are probably wondering why we go to the trouble of using a second 10MHz crystal oscillator to provide the 100ns pulses for the phase error counter. Why not just use the output of the main temperature-controlled 10MHz oscillator, at upper right?

We use a second 10MHz oscillator because this inevitably drifts in phase compared with the main oscillator and this introduces a small amount of "dither" into the phase error counting operation. The random noise introduced into the DAC's output voltage as a result of this dither allows the PLL's error correction to have a significantly higher resolution than if we used pulses from the main 10MHz oscillator.

The reason for this is quite straightforward. If we had used the pulses from the main oscillator, the fact that they would be locked to the 50kHz pulses (and hence the phase error pulses as well) would mean that the DC error voltage could only ever change in 19.53mV increments. This corresponds to 100ns changes in phase error. However, the dither introduced by using the second oscillator means that the average error voltage will change in somewhat smaller increments. And that means that we can maintain the main oscillator's phase locking to much closer than 100ns.

As shown in Fig.1, the DC phase error voltage from the DAC is fed through a buffer to a low-pass filter stage based on capacitor C1 and resistors R1 & R2. The filtered error correction voltage is then used to control the capacitance of a varicap diode, to fine-control the frequency and phase of the main 10MHz oscillator.

This unusual type of PLL system is very effective when it comes to phase-locking a 10MHz oscillator to the GPS 1Hz pulses but it does have a limitation. Because it divides down

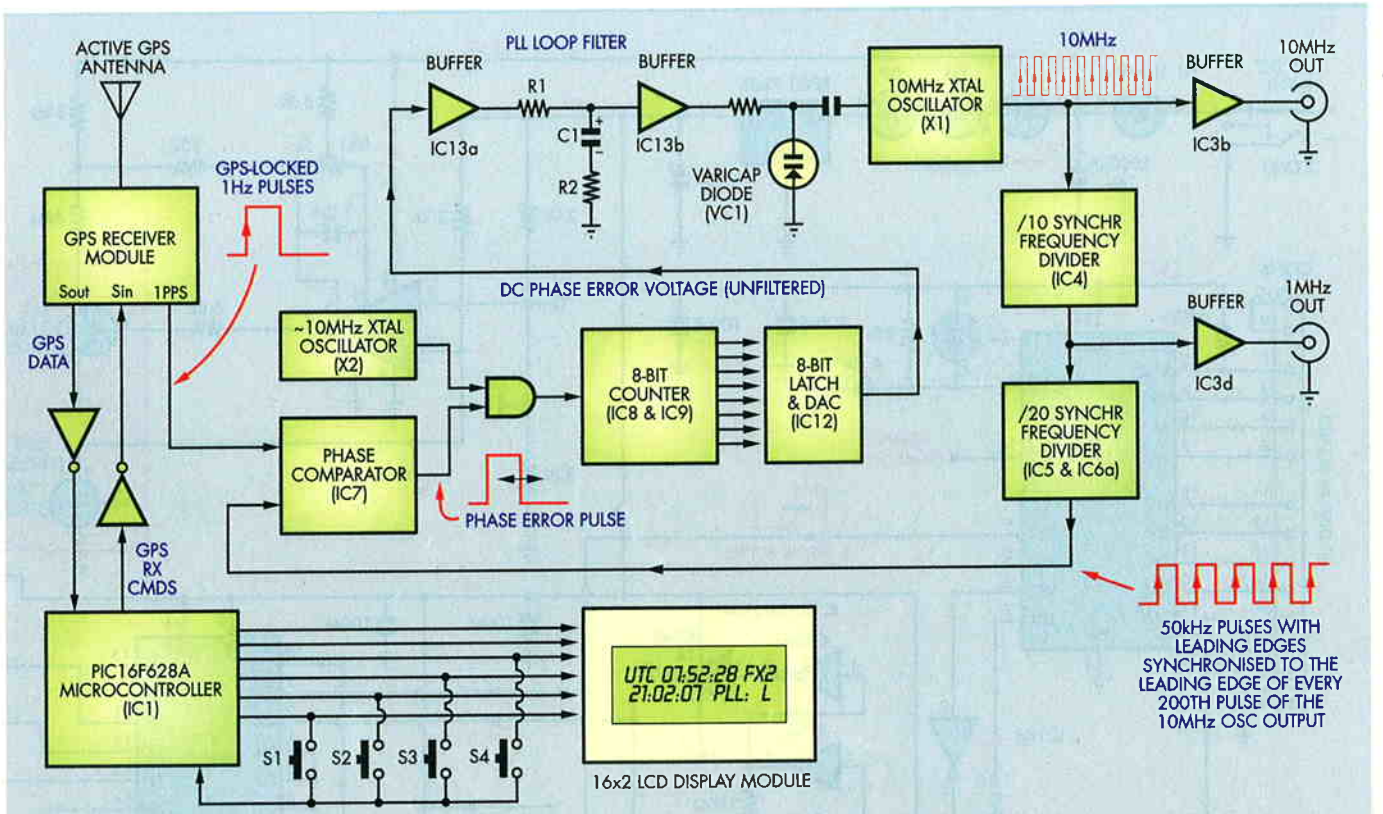


Fig.1: the GPS-Based Frequency Reference uses a phase-locked loop (PLL) to control the frequency of a 10MHz crystal oscillator (top, right). This PLL in turn is referenced to the very accurate 1Hz pulses from the GPS receiver module. A PIC microcontroller decodes the GPS data, interprets the switches and drives the display module.

the oscillator frequency by only 200 times instead of 10,000,000, it's just as effective at phase-locking an oscillator at a frequency of 9.999800MHz or 9.999600MHz, or 10.000200MHz or 10.000400MHz.

In other words, it's capable at phase-locking at frequencies that are separated from 10.000000MHz by exactly 200Hz or multiples of that frequency difference. This means that when you are setting up the frequency reference, it's very important to adjust the free-running frequency of the main crystal oscillator to within 100Hz of 10.000000MHz. If you don't, the PLL may lock it to 9.999800MHz or 10.000200MHz instead of the correct frequency!

Making use of the data

OK, that's how the main part of the GPS Frequency Reference works. The only part we haven't discussed yet is the section down in the lower left of the block diagram. This section is functionally quite separate from the main section. Its purpose is to make use of the stream of useful data that emerges from the GPS receiver module each second, along with (but separate from) those accurate 1Hz pulses.

This data is delivered as ASCII text and appears at the module's RS-232C serial output port. It's in the form of coded data "sentences", sent at a rate of 4800bps (bits per second) using a sentence format known as NMEA1083. This format was first standardised by the US National Marine Electronics Association (NMEA) for information exchange between marine navigation equipment.

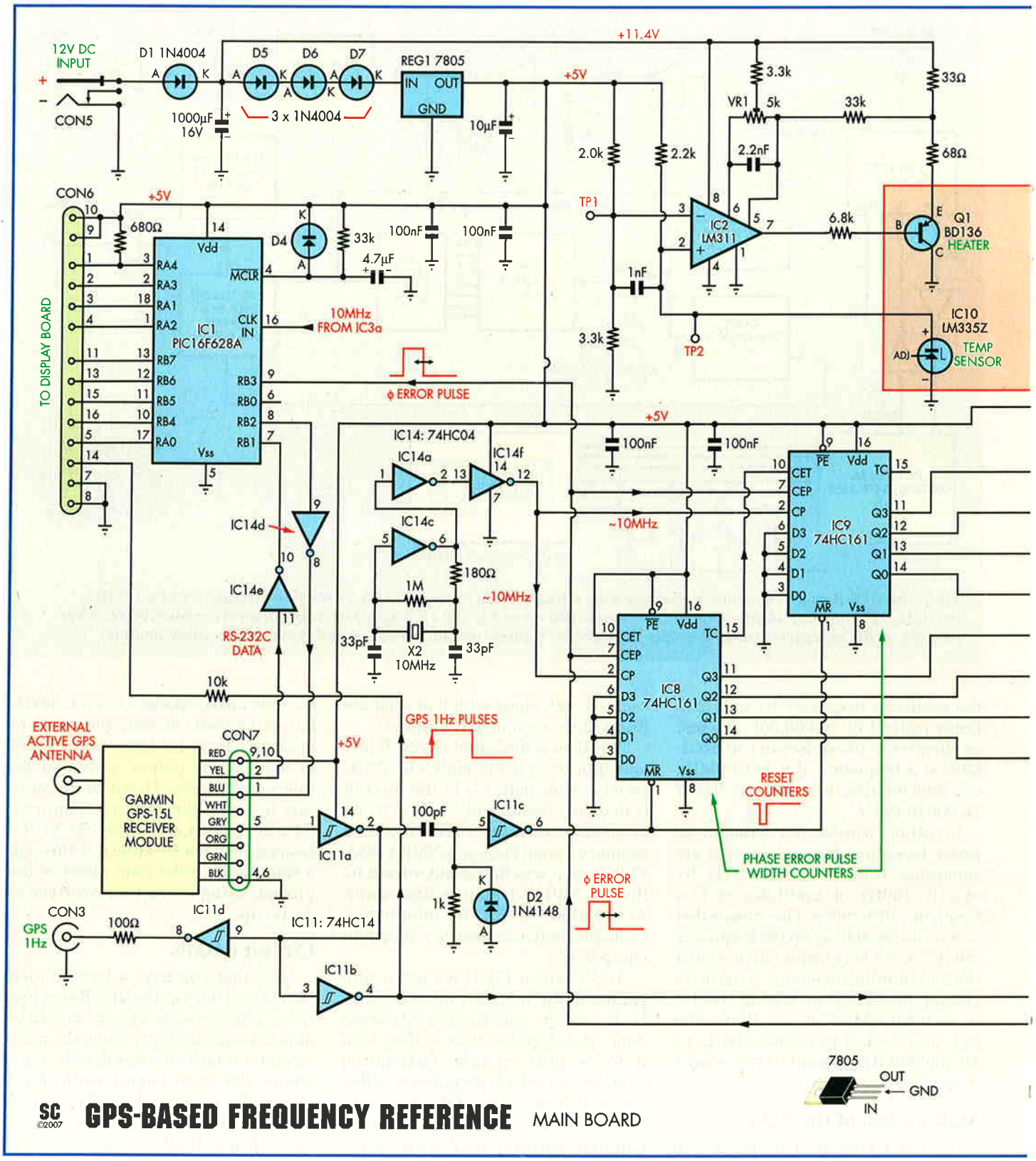
As shown in Fig.1, we use a programmed PIC16F628A microcontroller to "catch" and analyse this serial data. The decoded data is then feed it to an LCD module. Pushbutton switches S1-S3 are included to allow you to display some of the more esoteric information for a short time, as required. Normally, the display simply shows the current UTC time and date (updated each second), plus the GPS fix and PLL locking status.

The fourth switch (S4) forces the PIC micro to send an initialisation code command to the GPS receiver module, to initialise it correctly if it ever becomes "confused" (the GPS receiver also contains a microcontroller, of course). In fact, the receiver module has an RS-232C serial input as well as the output, provided for this very purpose. However, because this initialisation is rarely required, S4 is not readily accessible like S1-S3. Instead, it must be accessed through a small hole in the front panel of the project, using a small screwdriver or probe tip.

Circuit details

Now that you have a basic understanding of the way the GPS-Based Frequency Reference works, we should be able to work quickly through the main circuit, to clarify the fine details. Fig.2 shows the main circuit while Fig.3 shows the associated display circuit with its LCD module. The two connect via a 16-way header cable.

In operation, the Garmin GPS 15L receiver module (lower left of Fig.2) is fed via an external active antenna. The resulting GPS-locked 1Hz pulses are on the grey wire of its 8-way output cable and this goes to pin 5 of a 10-way IDC line socket that mates with CON7. The 1Hz pulses are then fed



SC ©2007 **GPS-BASED FREQUENCY REFERENCE** MAIN BOARD

through Schmitt inverters IC11a and IC11b which act as buffer stages. The resulting 5V p-p pulses from IC11b are then fed directly to pin 14 of IC7, which is the phase comparator.

The 10MHz crystal oscillator that's phase locked to the GPS pulses is based on inverter IC3f and crystal X1, plus varicap diode VC1 and several low-value capacitors. Its 10MHz output is fed via inverting buffer stage IC3b to CON1 and also via IC3c to divider stage IC4. This stage divides the signal by 10 and provides two 1MHz outputs, at pins 12 & 15. The pin 12 output is then fed via inverter IC3d to CON2, to provide the 1MHz output signal at BNC connector CON2.

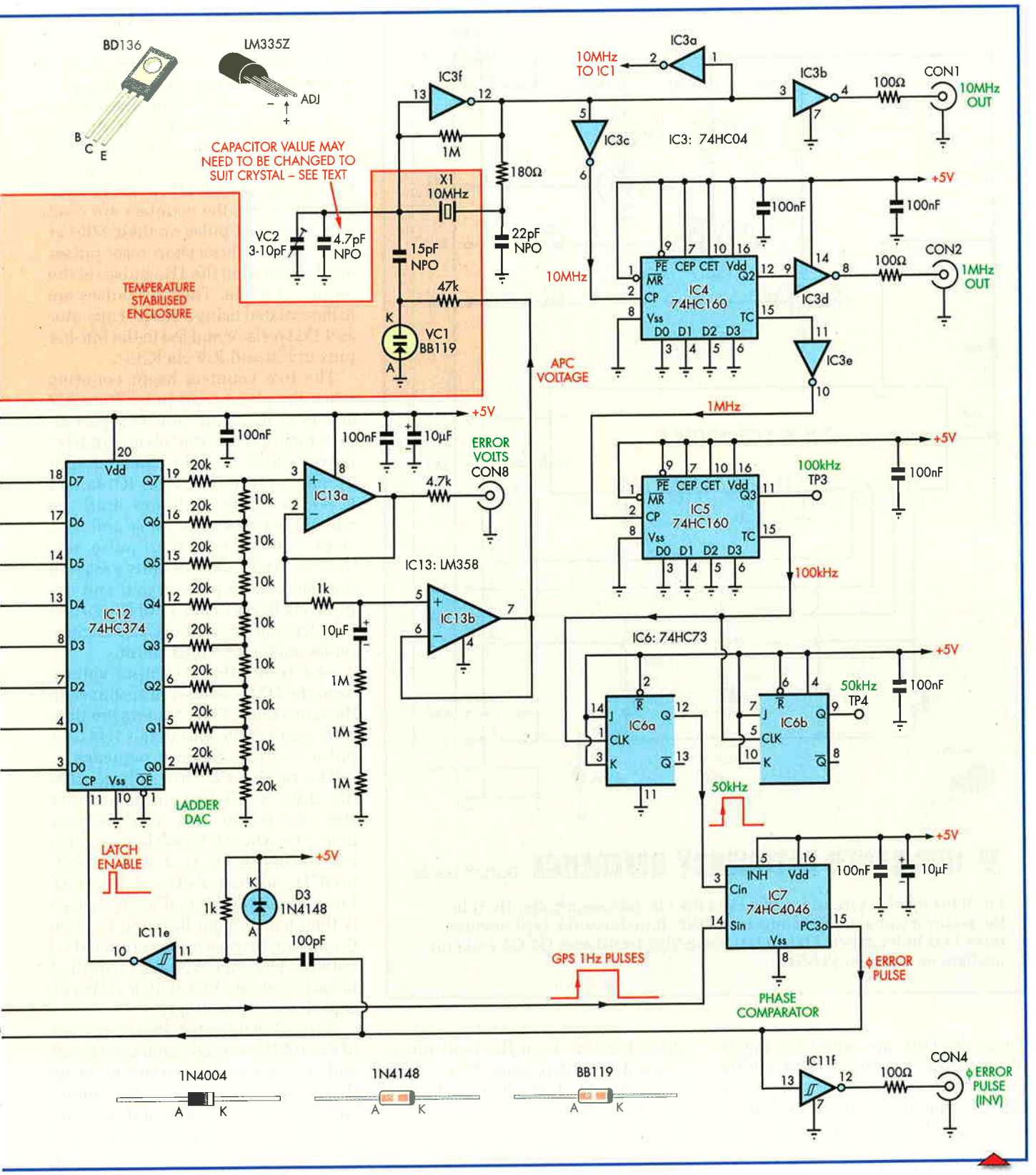


Fig.2 (above): the complete circuit for the GPS-Based Frequency Reference minus the display circuitry (LCD & LED indicators). The PLL-controlled 10MHz oscillator is built into a small temperature-controlled oven to ensure stability, with power transistor Q1 acting as the oven heater.

By contrast, the pulse output from pin 15 is fed via IC3e to a second divide-by-10 stage based on IC5. IC3e is necessary to invert the signal at the input of IC5, because the 74HC160 triggers on the resulting rising signal edges and it's these edges that are synchronised with the 10MHz oscillator signal.

The resulting 100kHz pulse output from pin 15 of IC5 is fed to the clock inputs of JK flipflops IC6a and IC6b.

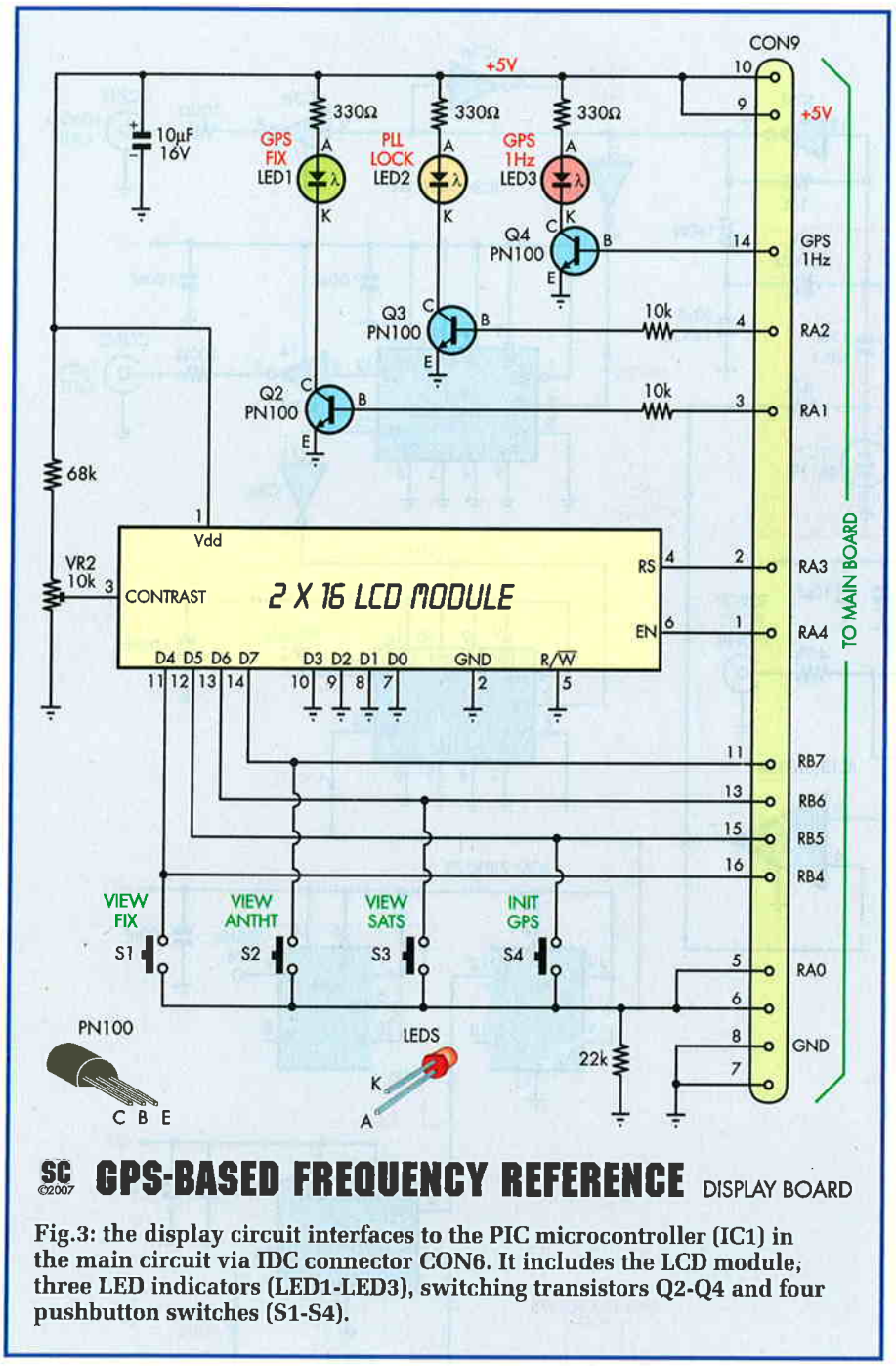


Fig.3: the display circuit interfaces to the PIC microcontroller (IC1) in the main circuit via IDC connector CON6. It includes the LCD module, three LED indicators (LED1-LED3), switching transistors Q2-Q4 and four pushbutton switches (S1-S4).

These are both are wired for toggle (divide-by-2) operation. The 50kHz pulses from the Q output (pin 12) of IC6a are then fed to the second input (pin 3) of phase comparator IC7, for comparison with the 1Hz GPS pulses. Note that these 50kHz pulses have their rising edges closely aligned with the rising edge of every 200th pulse from the 10MHz oscillator.

The phase error pulses emerge from pin 15 of IC7 and are fed directly to the clock gating inputs of 4-bit synchronous counters IC8 and IC9 (74HC161), which together form the 8-bit phase error pulse width counter. This is done because the AND gate shown in Fig.1 is actually inside the two counter chips, rather than being a separate device.

The "about-10MHz" clock oscillator used by the error counter is based on crystal X2 and inverter stage IC14c. Its output is buffered by IC14a & IC14f and fed to the clock inputs (pin 2) of the two counters. The eight output bits from the two counters are then fed to the data inputs of IC12, the octal latch. Its outputs are used to drive the resistive-ladder DAC (digital-to-analog converter).

In practice, this counter-latch-DAC sub-circuit is arranged so that it performs a new count of the phase error pulse width at the start of every 1Hz pulse from the GPS receiver module. The sequence is as follows: on the falling edge of each 1Hz pulse (100ms after the start), the counters are reset by a very short pulse on their MR-bar pins (pin 1). These short reset pulses are derived from the 1Hz pulses at the output of IC11a. The 1Hz pulses are differentiated using a 100pF capacitor and 1kΩ resistor and fed to the MR-bar pins of IC8 and IC9 via IC11c.

The two counters begin counting when the phase error pulse from IC7 arrives at their CEP pins (7). This allows them to count the "about-10MHz" pulses which are fed to their CP (pin 2) inputs via buffer stages IC14a and IC14f. Counting continues until the end of the phase error pulse and then stops. Another very short pulse, this time derived from the falling edge of the phase error pulse signal and applied via IC11e to pin 11 of IC12, then transfers the count into IC12's latches, replacing the previous count.

As a result, the DC output voltage from the DAC changes in response to the new count. The counters are then reset again at the end of the 1Hz GPS pulse, ready for the next sequence.

The varying DC error voltage from the DAC is fed first through buffer stage IC13a and then to a low-pass loop filter which is formed using a 1kΩ resistor (R1 in Fig.1), a 10µF capacitor (C1) and three 1MΩ resistors (R2). From there, the filtered error voltage is then fed through IC13b to become the automatic phase correction (APC) voltage. This APC voltage is applied to varicap diode VC1 which varies its capacitance accordingly.

As previously stated, VC1 forms part of the 10MHz crystal oscillator circuit and its capacitance variations bring the oscillator into phase lock. Trimmer capacitor VC2 and its parallel 4.7pF capacitor are used to initially adjust the oscillator so that its free-running frequency is within 100Hz of 10MHz – ensuring that the PLL locks correctly to this frequency.

Temperature stabilisation

OK, so that's the basic PLL section of the GPS-Based Frequency Reference circuit. By now, though, you're prob-

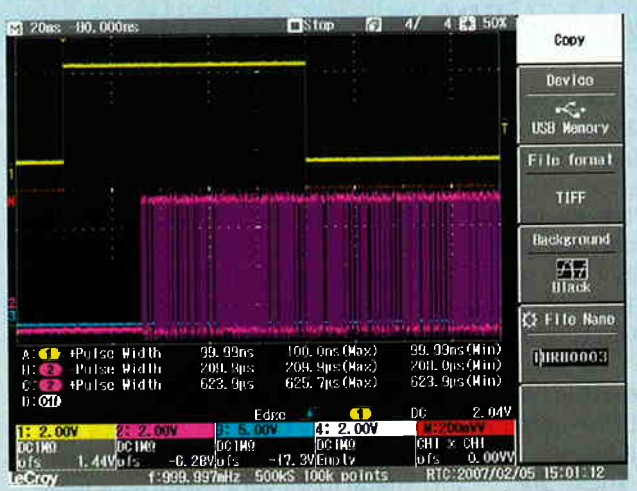


Fig.4: here are the two outputs provided by the Garmin GPS 15L receiver module. The upper trace (yellow) shows one of the extremely accurate 1Hz pulses, while the lower (purple) trace shows the start of the RS-232C data stream giving UTC time and date, latitude and longitude, etc. Note that the frequency reading on the bottom line should read exactly 1.000000Hz; the actual reading shows the scope's measurement error.

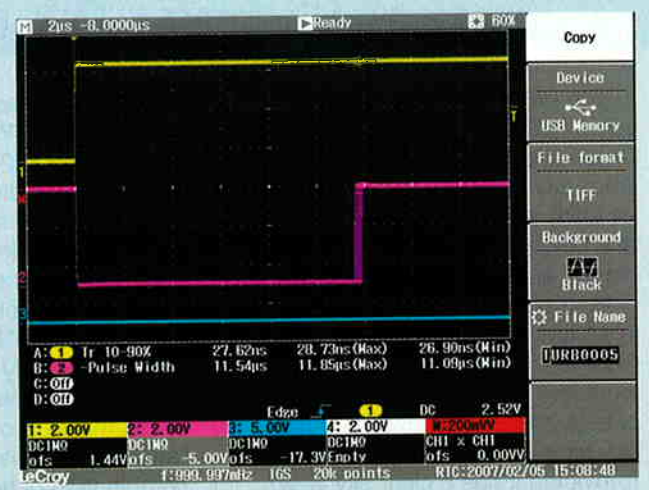


Fig.5: shown here are the leading edge of the GPS 1Hz pulses from the receiver module (upper yellow trace), and the inverted error pulse from the Frequency Reference's phase detector (lower purple trace), when the PLL is locked with a fixed phase error of 11.54us. The jitter visible on the trailing edge of the error pulse is normal and is caused by noise, GPS propagation variations and so on (see text).

ably wondering about the function of comparator IC2, transistor Q1 and the LM335Z temperature sensor (IC10). What are they for?

These parts are used to achieve temperature stabilisation of the main 10MHz oscillator crystal (X1), varicap diode VC1 and its series 15pF capacitor. In practice, these components are housed in a "mini oven" to keep the temperature constant. This oven includes a small TO-220 heatsink to which is attached the crystal, the LM335Z temperature sensor and a power transistor (Q1). It's basically an insulated enclosure made from a cut-down 35mm film canister which is lined inside using expanded polystyrene.

The construction of this mini oven will be described next month. All you need to know for now is that IC10 (LM335Z) is mounted inside the enclosure to sense the internal temperature.

Basically, the voltage across IC10 is directly proportional to its temperature (in Kelvins) and this voltage is applied to the non-inverting input of comparator IC2. IC2's inverting input is fed with a reference voltage of close to 3.15V, derived from a voltage divider (2kΩ & 3.3kΩ) across the regulated 5V supply rail. As a result, IC2's pin 7 output switches high when the temperature sensor's voltage rises slightly above 3.15V and switches low when the sensor's voltage falls somewhat below this level (depending on the hysteresis applied to the comparator).

IC2 is used to control power transistor Q1, which is used here purely as a heater. This transistor is attached to the finned heatsink which forms the frame of the mini oven, so when it conducts it generates heat to increase the temperature. As a result of the feedback provided by IC10, the temperature inside the mini oven is maintained

Specification Summary

(1) This unit is a low-cost frequency and time reference based on a Garmin GPS 15L receiver module. It is able to control the frequency of a local 10MHz crystal oscillator by reference to the very accurate 1pps (1Hz) pulses broadcast by GPS satellites (referenced back to UTC as maintained by the USNO). This allows the frequency of the local 10MHz oscillator to be controlled to within about 0.2Hz averaged over a 30-second period and even more tightly when averaged over a longer period such as 30 minutes.

(2) The built-in 10MHz reference crystal is housed in a small temperature stabilised enclosure or "mini oven". Buffered 10MHz and 1MHz outputs are provided for external use. Buffered outputs are also provided for the 1Hz GPS pulses and the phase error signals from the internal phase-locked loop (PLL) used to control the 10MHz oscillator. The error signals allow the user to log instantaneous phase error in the PLL, if this is desired for traceability.

(3) The unit provides a continuously updated display on an LCD module, showing UTC time and date, GPS fix and PLL lock status information. It also allows optional short-term display of receiving antenna latitude, longitude and height above mean sea level, plus the number of satellites in current view and their reception quality.

(5) The complete reference operates from 12V DC, which can be from a battery or a mains power supply. Average current drain is approximately 340mA, while peak current drain is about 420mA.

A Few Facts About GPS

The GPS satellite network is controlled and operated by the US Department of Defense (US DOD). Currently there are between 22 and 24 GPS satellites orbiting the Earth at a height of 20,200km, in six fixed planes angled at 55° to the equator.

Each satellite orbits the Earth in 11 hours 58 minutes – ie, about twice each day. This means that at least four satellites are within "view" of a given GPS receiver at almost any time, wherever it is located (providing it has a clear sky view).

The GPS satellites broadcast pseudo-random spread spectrum digital code signals on two UHF frequencies: 1575.42MHz (known as "L1") and 1227.6MHz ("L2"). There are two different code signals broadcast: the "coarse acquisition" or C/A code, broadcast on L1 only, and the "precision" or P code broadcast on both L1 and L2. Most commercial GPS navigation receivers process only the L1 signal.

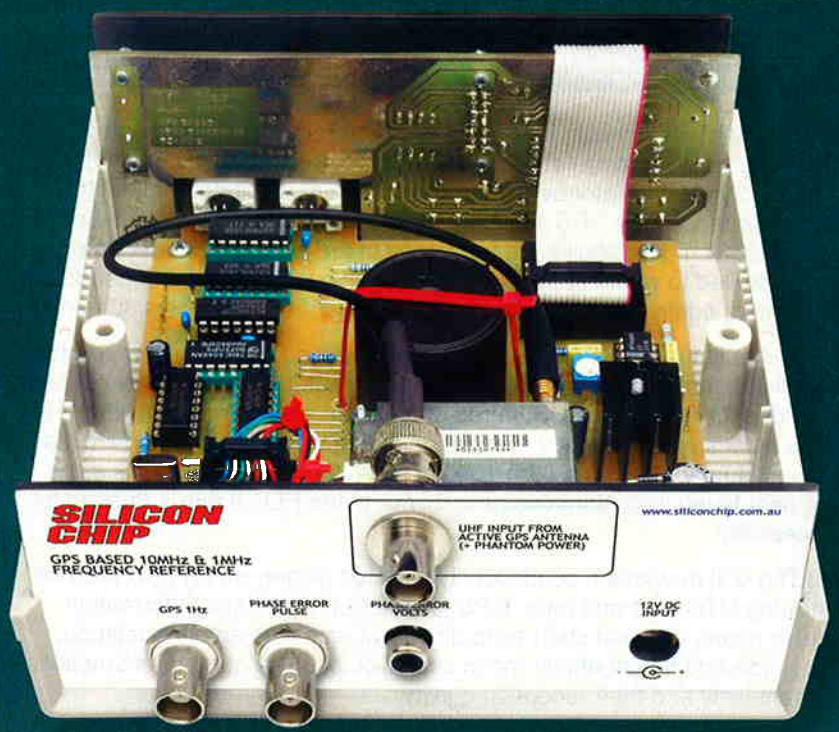
Each GPS satellite carries either caesium-beam or rubidium vapour "atomic clock" oscillators, or a combination of both. These are "steered" from US DOD ground stations and are referenced back to Coordinated Universal Time (UTC), as maintained by the US Naval Observatory (USNO) – itself kept within 100ns of UTC as maintained by the US NIST. This ensures they provide an accurate reference for both the carrier frequencies and the code signals from each satellite.

Although the GPS network was designed mainly for accurate terrestrial navigation, the high frequency and time accuracy of the signals from the satellites has made them very useful as a reference source for frequency and time calibration.

How Accurate Is It?

What kind of frequency accuracy can you get from this DIY GPS reference? Well, the 10MHz output is accurate to within 0.2Hz, averaged over a 30-second period. It's even more accurate when averaged over a longer period, such as 30 minutes or an hour.

The accuracy of the 1MHz output is the same in relative terms, since it's derived from the 10MHz output by frequency division. So it's quite reasonable to describe the nominal frequency accuracy as within two parts in 10^8 – considerably better than a free running crystal oscillator, and good enough for most frequency calibration purposes.



The rear panel carries BNC sockets for the antenna and for the GPS 1Hz and phase error pulse outputs, plus an RCA socket for the phase error voltage. It also provides access to the DC power socket.

at very close to 42°C (315K) – within about ±1°, in fact. The exact temperature can be adjusted over a small range using trimpot VR1.

RS-232C data

The RS-232C data from the GPS receiver module emerges on the yellow lead and is connected (via the IDC line socket) to pin 2 of CON7. From there, it's fed through inverting buffer IC14e to the RB1 input (pin 7) of PIC microcontroller IC1, which is used to process the serial data.

Similarly, the RS-232C serial input for the GPS receiver module is its blue lead and this goes to pin 1 of CON7. As a result, initialisation commands from the micro's serial output (RB2, pin 8) are fed to the module via inverting buffer IC14d.

The phase error pulse from IC7 is also fed to the RB3 input (pin 9) of IC1, so that the micro is able to monitor whether or not the PLL is maintaining lock.

Display circuit

The display circuit (Fig.3) interfaces to the main circuit via connector CON9 and includes the 2-line x 16-character LCD module – which is directly driven by microcontroller IC1 – plus its contrast control VR2.

In addition, there are the four control switches (S1-S4) plus three status indicator LEDs (LED1-LED3), in turn driven by transistor switches Q2-Q4. Note that Q2 & Q3 (and thus LED1 & LED2) are controlled by the micro itself (via RA1 & RA2), whereas Q4 (LED3) is

GPS Frequency Reference: Parts List

1 ABS instrument case, 158 x 155 x 65mm
1 Garmin GPS 15L GPS receiver module
1 external active GPS antenna to suit – see text
1 PC board, code 04103071, 142 x 123mm
1 PC board, code 04103072, 144 x 58mm
1 16x2 LCD display module, Jaycar QP-5516 or QP-5515
2 T0-220 heatsink, PC-mount (Jaycar HH-8516)
3 SPST PC-mount snap-action pushbutton switches (black)
1 SPST PC-mount mini pushbutton switch
2 10MHz quartz crystals, HC-49U package
4 PC-mount BNC sockets (CON1-CON4)
1 PC-mount 2.5mm concentric DC socket (CON5)
2 16-pin IDC line sockets
2 PC-mount 16-pin IDC header plugs (CON6, CON9)
1 10-pin IDC line socket
1 PC-mount 10-pin IDC header plug (CON7)
1 PC-mount RCA socket (CON8)
1 Panel-mount BNC-BNC male-male adapter
2 8-pin IC sockets, machined clip type
4 14-pin IC sockets, machined clip type
5 16-pin IC sockets, machined clip type
1 18-pin IC socket, machined clip type
1 20-pin IC socket, machined clip type
3 M3 x 15mm tapped spacers
2 M3 x 6mm machine screws, round head
7 M3 machine nuts
3 M2 x 25mm machine screws, round head
4 M2 x 12mm machine screws, round head
7 M2 machine nuts
7 M2 flat washers and star lockwashers
1 7x2 length of DIL pin header strip
7 1mm PC board terminal pins
1 35mm film canister, 34mm dia. x 34mm long
2 cable ties
1 5kΩ horizontal mini trimpot (VR1)
1 10kΩ horizontal mini trimpot (VR2)

Semiconductors
1 PIC16F628A microcontroller programmed with GPSFrqRF.hex (IC1)
1 LM311 comparator (IC2)
2 74HC04 hex inverters (IC3,IC14)
2 74HC160 synchronous decade counters (IC4,IC5)
1 74HC73 dual flipflop (IC6)
1 74HC4046 phase comparator (IC7)
2 74HC161 synchronous 4-bit counters (IC8,IC9)
1 LM335Z temperature sensor (IC10)
1 74HC14 hex Schmitt trigger (IC11)
1 74HC374 octal D-type flipflop (IC12)
1 LM358 dual op amp (IC13)
1 7805 +5V regulator (REG1)
1 BD136 PNP power transistor (Q1)
3 PN100 NPN transistors (Q2-Q4)
1 5mm green LED (LED1)
1 5mm red LED (LED2)
1 5mm orange/yellow LED (LED3)
4 1N4004 diodes (D1,D5-D7)
3 1N4148 signal diodes (D2-D4)
1 BB119 varicap diode (VC1)

Capacitors
1 1000µF 16V RB electrolytic
4 10µF 16V RB electrolytic
1 10µF 25V tantalum
1 4.7µF 25V tantalum
11 100nF multilayer monolithic ceramic
1 2.2nF MKT metallised polyester
1 1nF MKT metallised polyester
2 100pF NPO ceramic
2 33pF NPO ceramic
1 22pF NPO ceramic
1 15pF NPO ceramic
1 4.7pF NPO ceramic
1 3-10pF N470 trimcap (white)

Resistors (0.25W, 1%)

5 1MΩ	1 2.2kΩ
1 68kΩ	1 2kΩ
1 47kΩ	3 1kΩ
2 33kΩ	1 680Ω
1 22kΩ	3 330Ω
9 20kΩ	2 180Ω
10 10kΩ	4 100Ω
1 6.8kΩ	1 68Ω
1 4.7kΩ	1 33Ω
2 3.3kΩ	

driven by the 1Hz pulses from the GPS module via IC11b. The microcontroller also scans the switches. As stated, S1-S3 are pressed to display specialised data on the LCD, while S4 initialises the GPS receiver module.

Power supply

Power for the circuit is derived from an external 12V DC supply (eg, a plugpack rated at 500mA or more). This is applied via power connector CON5 and diode D1 which provides reverse polarity protection.

Diodes D5-D7 provide a supplementary voltage drop to reduce the power dissipation in 3-terminal regulator REG1, which delivers a regulated +5V rail to power most of the circuitry. The only sections driven directly from the unregulated +11.4V input are comparator IC2 and heater transistor Q1 in the mini oven.

Other signals

That's about it for the circuit description, except to note that various useful signals (in addition to the main 10MHz and 1MHz outputs) are brought out of the frequency reference to allow its operation to be monitored.

First, the very accurate 1Hz GPS pulses are brought out via IC11d and CON3. Second, an inverted version of the phase error pulse from IC7 is brought out via IC11f and CON4. And finally, the unfiltered DC error voltage from IC13a is brought out via CON8. Either of the last two signals can be used for logging the reference's operation.

That's all we have space for this month. Next month, we'll show you how to build it and describe the setting up and adjustment procedures. SC

SIMPLE DIGITAL for low-voltage me

Here's one of those really handy little projects that will cost very little but make life a whole lot easier when you want to measure voltage and current at the same time.

Everyone would have a digital multimeter these days. Even the quite cheap ones have a huge range of measurements. All do the usual voltage, current and resistance but many throw in continuity (often with a buzzer), capacitance, transistor and diode checking, inductance, battery checking and so on.

And when we say cheap, we mean it. You regularly see DMMs for less than ten dollars; indeed one retailer, Altronics (who happen to have a catalog in this issue) has even given DMMs away to customers when opening a new store!

So why would anyone want to build a project such as this which simply measures one range of voltage and one range of current?

And just as importantly, probably costs as much (if not more than) one of those many-function multimeters?

The idea for this project arose when we were "playing around" with batteries and chargers (SILICON CHIP, December 2006 and January 2007). Two of the things you must know, and know instantly, when designing chargers and charging batteries are, of course, current and voltage.

Even with several multimeters available (and used) I was always swapping leads around, trying to work out which leads belonged to which meter (Murphy's law variation 1.3.3: multiple test leads, especially of the same colour, will automatically tangle and lead to errors).

It occurred to me that what was really required was a simple meter capable of reading volts and amps at the same time.

Of course, those two are mutually exclusive. Voltage is measured in parallel with a circuit, current is measured in series (see the panel "*Meter Shunts and Multipliers*").

But what if we had one device capable of doing both?

This is it: SILICON CHIP's simple answer to an oft-occuring problem.

And when we say

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PANEL METER easurements

by ROSS TESTER

simple, we mean it: two digital panel meters in one small case, one set up to measure 20V DC and the other set up to read 20A DC. And if those ranges don't suit your application, they can be easily changed.

However it seemed to us that charging a variety of batteries up to 12V, a 20V maximum was about right. 20A might seem a bit excessive but if you're charging car batteries, you could need that sort of reading. Again, if you want to change it, you can!

The digital panel meters automatically scale down to show milliamps anyway, if that's what you need.

Which way to go?

As I just mentioned, it's based on a couple of panel meters. I toyed with the idea of using analog meters for a millisecond or two but digital meters are much better for reading relatively constant voltages and currents – one glance and you've got it. Analog meters come into their own when looking for changes in values – you can get a pretty good idea of the way a circuit is behaving by looking at the speed of change.

Of course, a 'scope is usually even better for that purpose, so if I wanted to I could hook up old trusty and look at pretty pictures. But that's further complicating the issue.

OK, so we were going to go with panel meters. As luck would have it, just at that time I was looking at an Oatley Electronics advert and out popped some quite cheap digital panel meters (Cat DPM1) – at just $9.00. And even better, out of the box, they are wired for 20V DC full scale.

So I picked up two of them along with a Jaycar sloping handheld enclosure (Cat HB6090) which looked just about the right size.

About this time that my attention was drawn to another Oatley Electronics project designed to work with these specific digital panel meters. It's an add-on isolation board with either shunt or divider for different voltages and current. It also has a built-in DC-DC isolated power supply to power the digital panel meter at a very economical 3-5mA.

Like most digital panel meters and digital multimeters, these meters do not have a common ground between the input and the battery.

As a result they cannot even measure the voltage of the battery that is powering them. If it is desirable to have a common ground between the input and the battery it is necessary to derive a "floating" power supply to

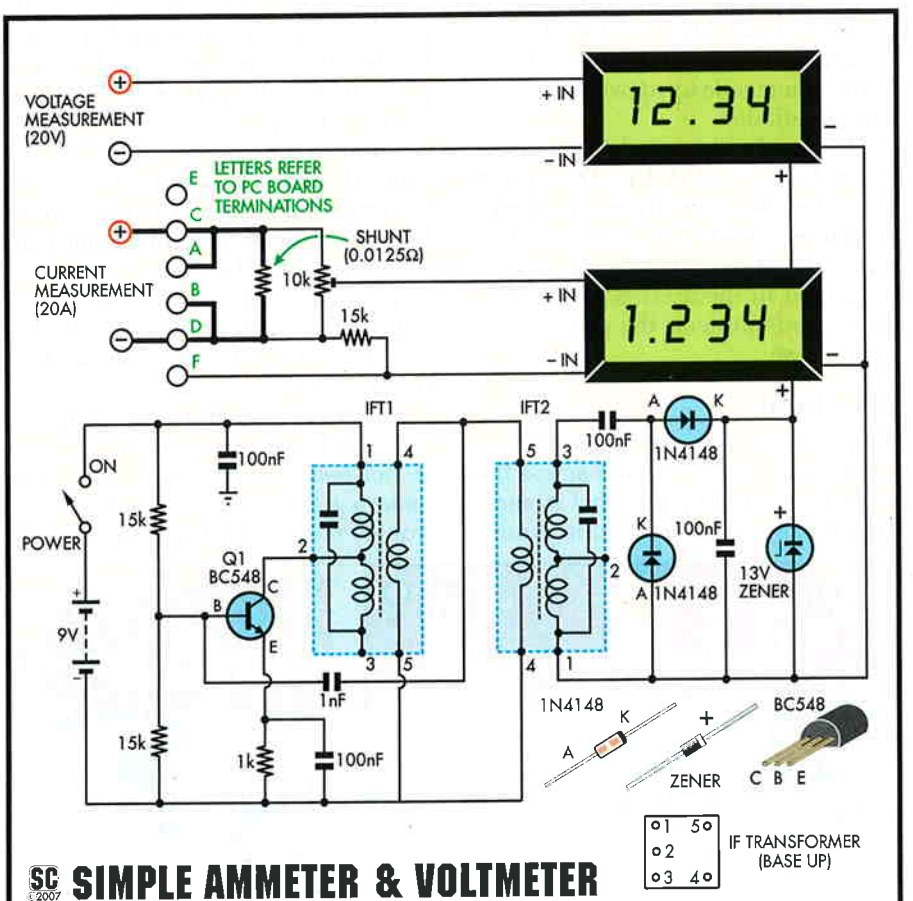
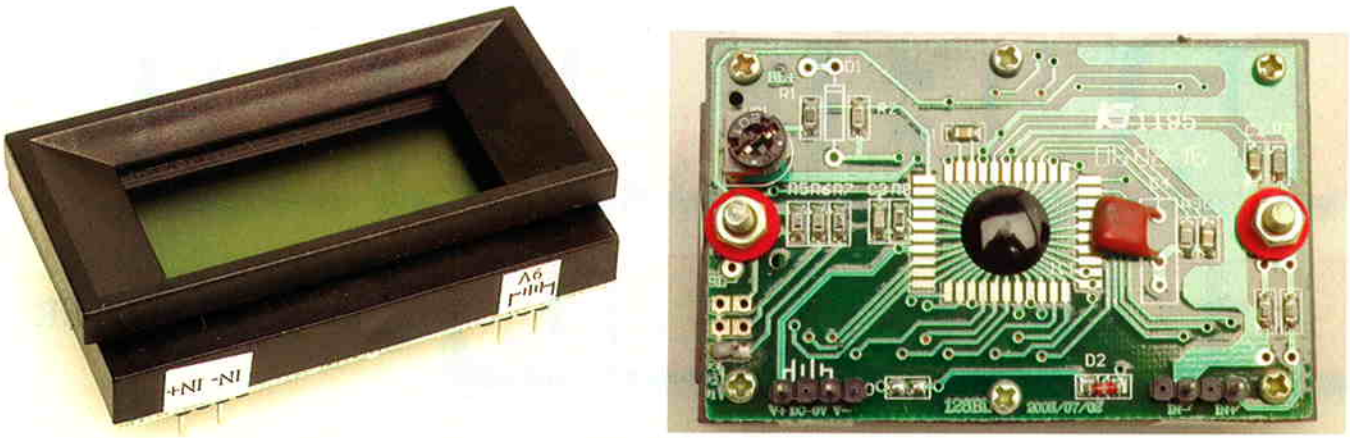


Fig.1: It could have been as simple as two digital panel meters (DPMs) and a 9V battery but the isolating power supply and shunt board only adds a few dollars to the price. It consists mainly of the oscillator based on Q1 and IF transformer IFT1, which is coupled to IFT2 and the voltage-doubler rectifier which follows. The 13V zener diode protects against over-voltage.



Here's the panel meter we used, with the rear view at right showing the chip which does all the work (the black blob in the middle). This one is from Oatley Electronics but is similar to many on the market. Note the labels on the side near the input (left) and power (right) pins – you can just see these at the bottom edge of the right-hand photo.

power the panel meter.

The lone transistor and its associated components form an oscillator with a frequency determined by the 455kHz IF transformer IFT1. The 1nF capacitor applies a feedback voltage from the transformer's secondary to the base of the transistor to maintain oscillation. The output from IFT1 is applied to the input of transformer IFT2. IFT2's output is applied to a voltage doubler made up of two capacitors and two diodes.

The panel meter supply can be anywhere from 7 to 11V DC. The output of this simple supply is nominally 9V but it is possible that it could go higher, especially if a higher input voltage is applied to the oscillator. The 13V zener diode protects the panel meter in this case.

The shunt

Of course, it would be possible to simply add a shunt resistor across the panel meter terminals so that it measures current. However, this would require trial and error in cutting the shunt length to get the meter reading the exact current.

To make life a lot easier, the shunt is instead wired to the add-on PC board which has provision to adjust the current reading via a voltage divider and preset pot.

The board is the same size as the panel meter and is designed to solder to and stack on the back. Like the panel meters, it's priced at $9.00 (Cat No K212).

One of these was added to the order (I figured that only one would be needed, that to set up the current-measuring meter. The voltage-measuring meter could be used "as is").

The only other things that were required were four heavy-duty terminals, a 9V battery holder and an on-off switch.

There's not much to this project – either in terms of complexity or cost! In fact, because of its low cost it would make a great project for a school electronics class; something they would find really useful once completed (especially as school electronics, by and large, is limited to battery-powered projects).

The voltmeter

As we mentioned before, the voltmeter is already configured to measure 20VDC. The only things we need to is provide connections between the case terminals and the appropriate pads on the PC board and supply power. We'll look at power shortly.

As a voltmeter is connected in parallel with the circuit under test, very little current flows. And because we are measuring only low voltage, heavy insulation isn't required.

Therefore the connecting wires can be as thin as you like – we used two strands from a ribbon cable but just about any insulated hookup wire is fine.

Just make sure it is routed out of the way of the battery case and power switch (especially when the case is assembled!).

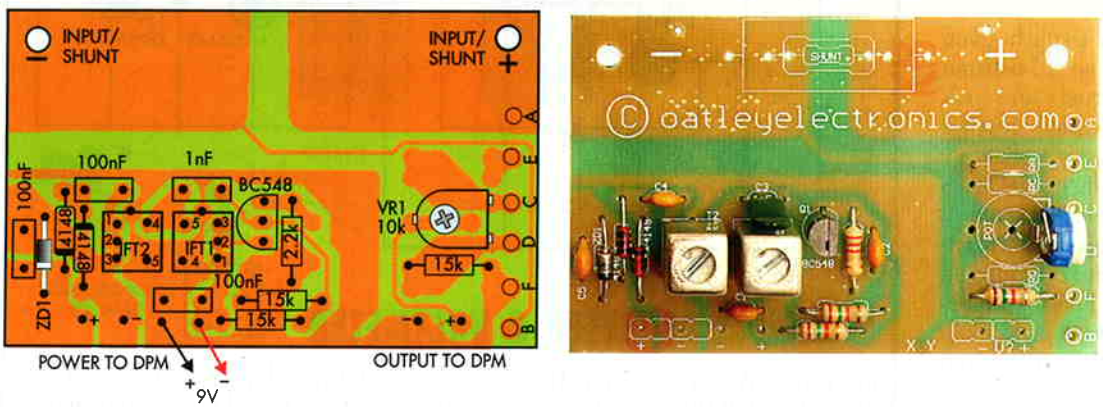
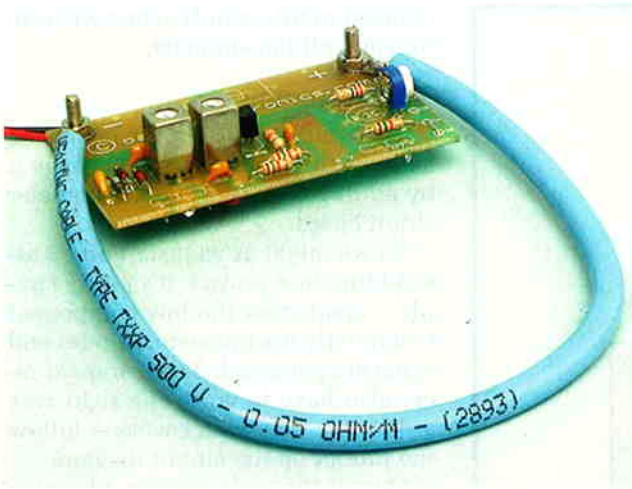


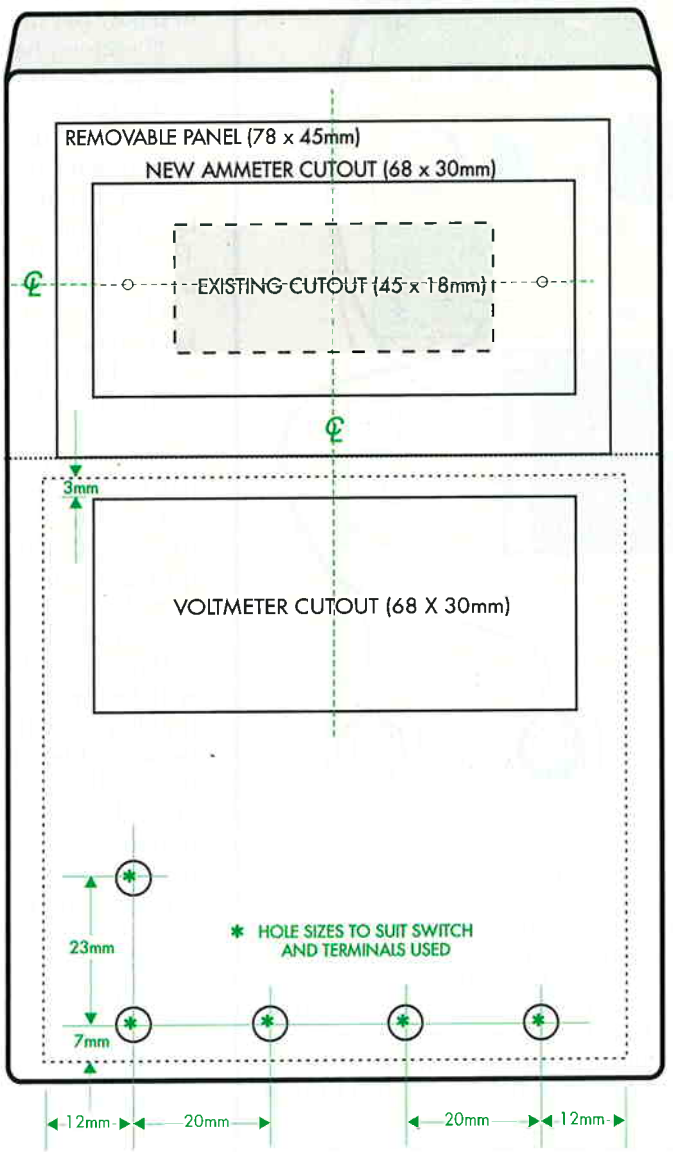
Fig.2: assembly of the Oatley K212 Shunt Board is pretty simple – only the diodes, transistor and the two IF transformers have any polarity issues. This board sits on top of the header pins on the Ammeter DPM with the pins soldered to its underside. This same PC board can also be used as a DPM multiplier (hence vacant holes) but we used the voltmeter DPM "as it came" with 20V FSD.

Power could be supplied direct from the 9V battery, via the on/off switch to appropriate pins on the PC board. But part of the ammeter (following next) is a DC-to-DC isolated power supply which can power the digital panel meter at a very economical 3-5mA. We checked: this can just as easily supply both DPMs.

So to keep everything simple we will



The heating-wire shunt shown fitted to the add-on shunt/power supply board. Note that this should be done *after* the board is soldered in place, not as shown here (just to show where it goes!) Similarly, the photo at right shows both panel meters in position but the shunt board has to be soldered in position to the top (ammeter) DPM.



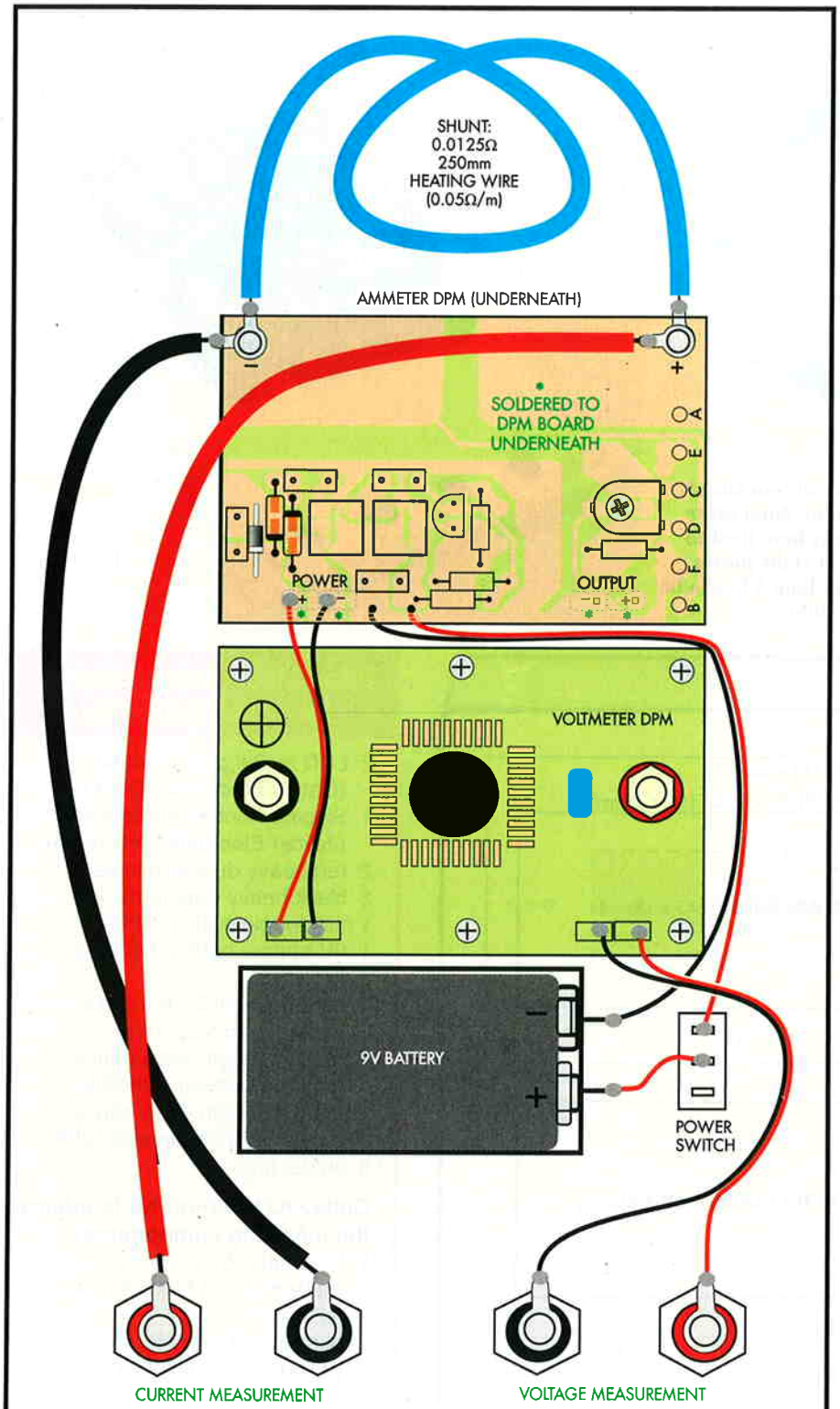
Drilling details for the Jaycar HB-6090 sloping front instrument case.

Parts List – Simple Digital Ammeter/Voltmeter

- 2 LCD digital panel meters (Oatley Electronics DPM1)
- 1 Sloping front instrument case (Jaycar Electronics HB-6090)
- 2 red heavy duty terminals
- 2 black heavy duty terminals
- 1 mini toggle switch, SPST
- 1 9V battery holder, PC board mounting
- 1 50mm length 2-strand ribbon cable (or hookup wire)
- 1 200mm length extra heavy duty red hookup wire (20A)
- 1 200mm length extra heavy duty black hookup wire (20A)
- 6 solder lugs

Oatley K212 Shunt Kit (contains the following components)

- 1 PC board, 67 x 43mm, originallly coded K116 but now K212
- 2 miniature IF transformers
- 1 BC548 NPN transistor
- 2 1N4148 silicon diodes
- 1 13V 400mW zener diode
- 3 100nF polyester capacitors
- 1 1nF ceramic capacitor
- 3 15kΩ 1/4W resistors
- 1 2.2kΩ 1/4W resistor
- 1 10kΩ preset potentiometer
- 1 length heating wire, (0.05Ω per metre) – see text
- 2 10mm M3 bolts each with 2 nuts and washers



Here's how it all goes together: the ammeter DPM is underneath the shunt board at the top (mounted on the sloping section of the case), with the tops of the four header pins on the DPM board (marked with an asterisk) soldered to the underside of the shunt board. Two wires also connect the "power" pins to the same pins on the voltmeter DPM board. Otherwise, it's pretty plain sailing. Note that the wiring from the current measurement terminals to the PC board is extra heavy duty; the wiring between the voltmeter terminals and its PC board can be light duty (we used two strands from ribbon cable).

connect to this supply when we have finished off the ammeter.

The ammeter

The ammeter starts off being the same as the voltmeter – we change it by adding the Oatley K212 ammeter shunt board.

So we might as well start off by assembling that project. It's pretty simple – apart from the low component count, only the transistor, diodes and zener are polarised. The IF transformers also have to go in the right way around or they won't work – follow the pinout on the circuit diagram.

One of the main reasons for using the ammeter shunt board is that it makes adding the required shunt a lot easier.

The shunt itself is a short length of resistance wire which is used for under-floor heating. This wire, which is included in the kit, has a resistance of 0.05Ω per metre.

Therefore, half a metre will have a resistance of 0.025Ω and 250mm will be 0.0125Ω – exactly the resistance we want for the shunt.

This wire is soldered to a pair of spade lugs and secured to the PC board by two small bolts in the top corners. The same bolts secure the cables from the ammeter input terminals.

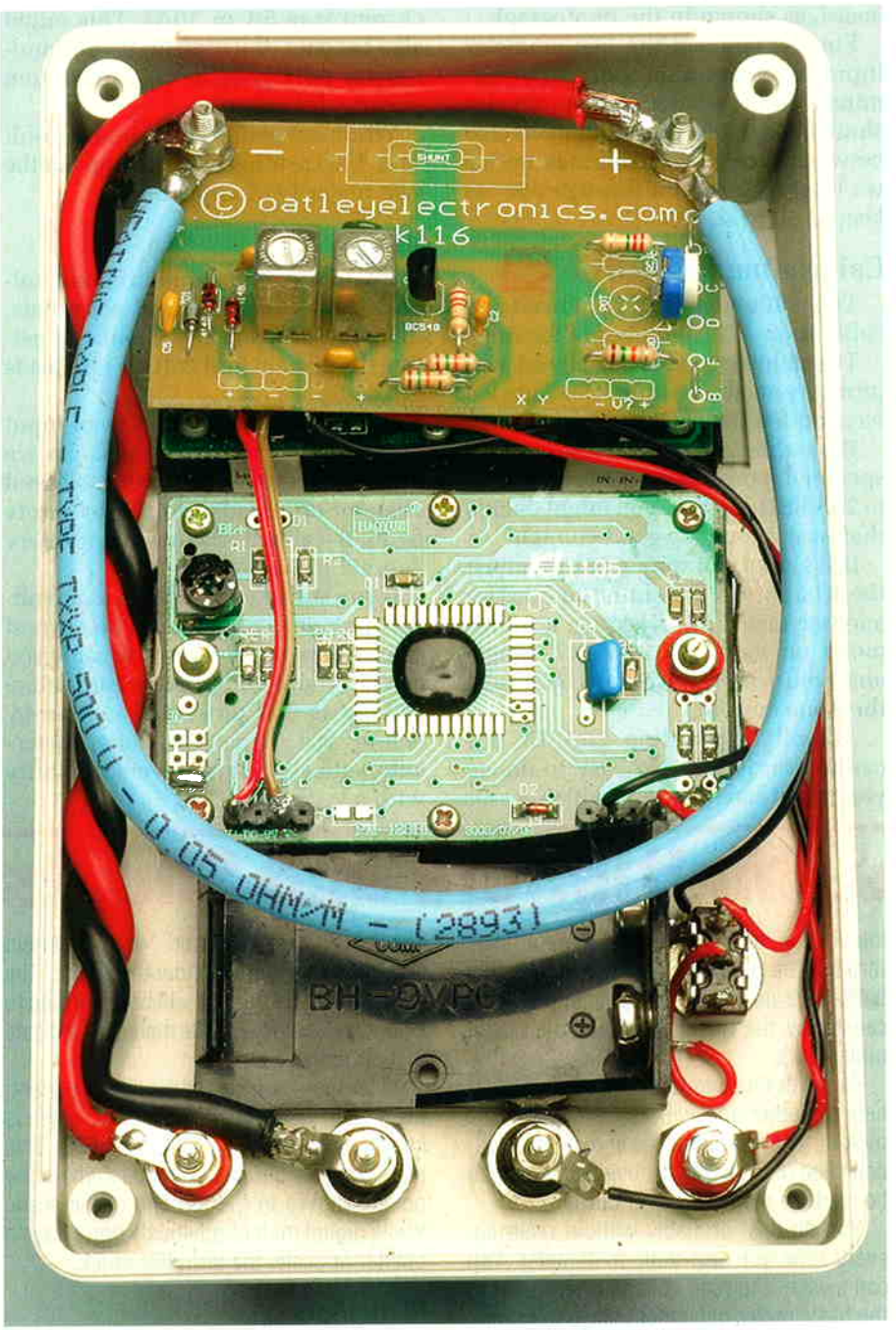
This means that heavy currents are kept off the PC board – the lion's share passes from the terminal, up the heavy cable, through the shunt and back to the terminal again.

This wire *does* need to be thick! It has to be able to carry up to 20A so ordinary hookup wire won't do. We used two short lengths of extra-heavy-duty automotive hookup wire, rated at 25A. These were also soldered to spade lugs.

When assembling the PC board, start with the two bolts. While there are two nuts on the bolts (one holds the bolt in place, the other secures the spade terminals), we also soldered the head of the bolt to the copper track on the opposite side of the PC board. That improves conductivity as well making the bolt captive.

To complete the shunt board assembly, solder a pair of thin, polarised hookup wire (or two strands from a ribbon cable) about 100mm long to the power connection pads on the PC board.

Leave the opposite end for the moment.



This slightly-larger-than-life photo also shows where everything goes. In this shot we've taken the loop out of the shunt (thick blue wire) because it hid too much underneath. But it needs to be looped so that the case bottom can screw on.

The case

The Jaycar case has a front panel divided into two sections. Most of it is flat, like any other case but there is a sloping section at the top.

For our purposes this was perfect because it allowed room for the current meter with the piggy-back shunt board. The voltage meter fitted immediately below this on the flat section, with the four terminals across the bottom. The battery holder fitted nicely into the area between the back of the terminals and the voltage panel meter – along with the on-off switch.

Some surgery is required on the case to fit the meters and mount the terminals and switch but this is quite easily accomplished (the case is ABS). Even better, the sloping section has a removable "face plate" with a cut-out obviously designed for a panel meter – unfortunately, though, not quite the right size for the Oatley meters.

We simply enlarged this cut-out to suit and then cut a similar-sized hole in the flat section of the case.

Mark the case according to Fig. x and then drill a row of very close holes – almost touching each other - along the inside of line with a fine (eg, 1mm or so) drill. If you have access to a drill press, this makes life so much easier.

When the row of holes is finished, elongate them so they form a slot. Break out the panel and smooth the cutout out with a fine file up to the line. While it's best to make the cutouts nice and neat, any small "oopses" should be hidden by the panel meter escutcheon. The case lid is effectively sandwiched by the panel meter.

When drilling the holes for the terminals, make sure you allow for the case mounting pillars in the corners. Remember you have to get a solder lug and nut/washer onto the terminals – if they are too close to the pillars, you won't be able to. We've shown measurements to help preclude problems.

The only 9V battery holder we could get was one intended for PC board mounting – we merely bent the pins out horizontal with a pair of pliers and soldered straight to them. A dollop of super glue or other adhesive is all that's necessary to hold the battery holder in place.

Right alongside this (next to the battery holder connections) is the on-off switch. A nice small switch looks best here but just about anything will be fine if it will fit!

Assembly

Assuming you have completed the shunt PC board, it's time for final assembly.

Start by mounting the voltage DPM on the flat of the case and then the current DPM on the sloping section. Both are mounted by removing their nuts, separating the front escutcheon from the display board proper and sandwiching the case between the two. Tighten up the nuts to lock in place.

Soldering the ammeter shunt board to the DPM is a little tricky because you don't have a lot of room to solder between the two boards.

You'll need a pretty fine soldering iron tip for this job. The power and output pads on the shunt board line up with the appropriate pins on the DPM. Note that this is done before attaching either the shunt or input

cabling, as it will just get in the way while you solder.

The appropriate pads on the shunt board line up with their respective pins on the DPM. The soldered joins are the only thing which holds the shunt board in position.

To complete the project you need to mount the four input terminals, the power switch and battery holder, run the heavy duty ammeter input cables and the light duty voltmeter input cables to their respective terminals and connect the power wires to the shunt board.

The latter are the other ends of the two wires you previously soldered to the power input pads on the ammeter shunt board. Solder the black wire direct to the "–" pin of the battery socket and the red wire first to the power switch, thence to the "+" battery socket pin.

Similarly, solder a pair of fine insulated wires (again, a pair from a ribbon cable is fine) between the two power supply pins on the ammeter board and the matching pins on the voltmeter board, as shown in the photograph.

Finally, connect the two ammeter input wires between their input terminals and the bolts on the ammeter shunt board, then the shunt itself also between those bolts. You may notice we looped the shunt through 360° to keep it all neat.

Calibrating the meters

The voltmeter should not need any calibration – it comes ready for use.

The ammeter, on the other hand, will probably need adjustment because we have added the shunt board.

With the 250mm of heating wire specified, you should get pretty close to 20A FSD – in fact, you might decide that near enough is good enough!

If it's not, you may need to adjust the trimpot on the shunt board. Use another meter in series (eg, a multimeter on its high "20A DC" range) and adjust the pot so they both read the same current.

Actually, providing 20A DC for calibration is not that easy to do, so you might have to do it with a lesser current (say 5A or 10A). This might also become a necessity if your multimeter only goes to 10A maximum – many do!

While not perfect, this should result in an FSD reading close enough for the vast majority of applications.

In use

If you can find some different coloured heavy-duty input terminals, this would mean less chance of getting the current and voltage clip leads mixed up.

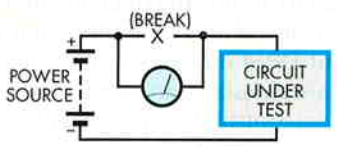
We couldn't – so both sets of input terminals are red and black. So we made up a couple of different coloured alligator clip leads (from heavy-duty figure-8 cable for current; ordinary figure-8 for voltage).

If you stick to red and black for voltage, polarity is obvious. The current cable can be any heavy-duty cable you can lay your hands on (eg, auto cable) as long as it is polarised – either by colour or a stripe. The panel meters automatically show reverse polarity with a "–" sign.

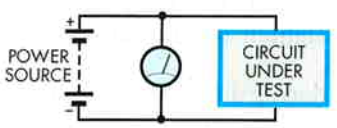
About Meters, Multipliers and Shunts

We've been talking at length about meter shunts and multipliers. But if you've never come across the terms before, they can be confusing. Fear not! Help is at hand . . .

Before we start, though, there are twofundamental and most important concepts which you must remember: *to measure current, the meter is connected in series with the circuit. To measure voltage, the meter is connected in parallel with the circuit.* This is shown below.



AMMETER – *IN SERIES*



VOLTMETER – *IN PARALLEL*

It may surprise you to learn that all meters, whether displaying current or voltage, are actually showing the current passing through them. When we are measuring current, all of the current has to flow through the meter. When measuring voltage, only a miniscule current flows through the meter (in fact, the smaller the better if we are not to get misleading readings caused by the meter "loading" the circuit under test).

OK, with those to facts under your belts, here's another one: with few exceptions, all meters, whether digital (as in our case here) or analog (ie, one with a moving pointer) can be made to read voltage or current.

You do this, probably without realising, every time you use your multimeter. You can switch it to read voltage or current but the basic meter movement stays the same. When you switch to a different voltage or current range, the switch connects various resistors inside the multimeter into and out of circuit. If you've ever taken the back off a multimeter you'll see a whole swag of resistors connected to the switch contacts.

These resistors are called shunts and multipliers and are, for the most part, simply very high precision resistors. In the case of shunts designed for high current, they have *extremely* low resistance (perhaps only a few milliohms or so).

Ohm's law in action!

Every meter has a certain amount of internal resistance. Apply a certain voltage across that "resistor", then a certain amount of current will flow through it. The exact amount of current will be according to Ohm's law (I=E/R) and the meter will indicate that current.

At the meter's designed maximum current, the pointer will indicate maximum, which is known as full scale deflection, or FSD. This term comes from analog meters where the pointer moves to the top end of the scale. While digital meters obviously don't have a pointer or scale, the term has stuck.

Multipliers

What happens if the meter is reading full scale and you add a resistor, exactly the same resistance as the meter, in series?

As the overall resistance is doubled, if the applied voltage stays the same, the current halves. Therefore the meter will read half.

That also means the meter can read higher voltages without risking damage. Using that same series resistor, you would be able to apply twice the voltage and the meter would read full scale.

Add a resistor that is ten times the meter's resistance and you would have overall eleven times the original resistance (the meter resistance itself plus the 10x series resistor), so you could apply eleven times

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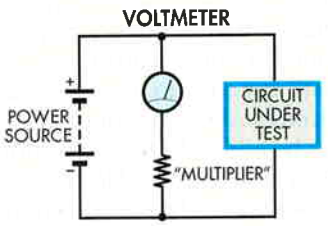


the voltage and the meter would once again read full scale.

This resistor is known as a multiplier and is found in all voltmeters – including your multimeter when it is switched to a voltage range.

In the multimeter a known high-precision resistor is connected in series with the meter movement which makes the meter read a certain voltage "full scale" (as set by the switch). Change the setting on the multimeter to a different voltage range and a different multiplier is switched in. The multimeter manufacturer marks the scale so that it reads directly in volts.

Resistors used for meter multipliers are much more accurate than normal resistors – it's not unusual for a multiplier to be accurate to one or more decimal places (eg, 100.3Ω). A normal 100Ω resistor, as you would use in a project, even one accurate to 1%, could actually be anywhere from 99Ω to 101Ω. That's not good enough for a meter multiplier. For the meter reading to be exact, the multiplier needs to be exact.

Shunts

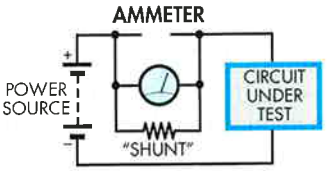
Most meter movements are designed to read full scale with *very* little current flowing through them. A typical analog multimeter movement might only need 50μA for FSD – obviously, far too low for most practical uses (we often want to read five or ten AMPS – 100,000 times as much or more!).

How do we do it?

We use a resistor in parallel with the meter movement. Some of the current will still pass through the meter but some will bypass the meter and flow through the parallel resistor. This resistor is usually very significantly lower in resistance than the meter movement.

It's called a shunt, because it "shunts" some (indeed, usually a lot!) of the current away from the meter.

With a known value meter movement and a known resistance shunt, you can work out what proportion of current flows through each and therefore you will know what overall current makes the meter read full scale.



The basic analog meter movement may only need, say, 1mA through it to read full scale. A typical resistance for this type of meter would be 200Ω.

If you want it to read 2mA instead, you would add another 200Ω resistor in parallel with the meter – each would take half the current, or 1mA, therefore the meter would show full scale for 2mA.

Say you wanted it to read 1A (1000mA)? You would need to make the shunt take 999mA and leave 1mA for the meter. From Ohm's law, you can work out that the meter has .001 x 200 or 0.2V across it when it is reading full scale; therefore your shunt resistor needs to be or .2/.999 or 0.2002Ω.

Maths time: what should the shunt resistor be if you wanted to have the meter read 10A? If you said 0.2/9.999 or 0.0200Ω, you'd be right.

Before we finish, what about a multimeter that reads Ohms? Believe it or not, this is simply a voltmeter powered by the multimeter's internal batteries. The resistance you are measuring becomes part of the multiplier and the meter reads its value direct. That's also why you cannot read resistance in a powered circuit – the voltage across the resistor in the circuit will almost certainly cause the multimeter to give a wrong reading. SC

SERVICEMAN'S LOG

Variations of the original mousetrap

It's amazing the tricks some people pull to get out of debt. Here's how one cunning rat paid off his rent arrears – with a dodgy TV set, no less.

It's amazing the range of consumer electronic equipment that's now available. However, while this is good for consumers, it does make it difficult for technicians to be proficient with all brands and models when it comes to servicing TV sets and displays. Fortunately though, most TV sets are variants of the "original mousetrap" and so similar troubleshooting procedures apply to all.

We also get the odd "orphan" that has strayed into our part of the world. For example, some months ago, a young man brought in a 51cm Panasonic TV/VCR designed for the US market. He had been given the set and it had a US mains plug fitted to the power lead.

I explained that it needed a 240/110V transformer to start with and even then it would only work with NTSC signals and the tuner wouldn't work in Australia. Disappointed, he took the set away and I thought that that would be the end of the matter.

I was wrong. A year or so later, a young woman brought in a similar set which she said was dead and which, she thought, probably needed a new fuse. Apparently, she had been given the set by her male flatmate in lieu of rent, her "friend" being well in arrears when he left.

At first I didn't recognise the set but it looked awfully familiar. Anyway, I searched for the model number on my computer database and up it popped.

It wasn't until I checked the serial number that the penny finally dropped and now I could piece the sequence of events together. Someone had fitted an Australian power plug and the fuse had indeed given out – after all, 240 into 110 won't go!

It turned out that what the cunning little rat had done was scavenge the set from the footpath during a council clean up and then deceived the poor girl into thinking it was a fair swap for the rent. After all, he said, it only needed a fuse!

Items Covered This Month

- Philips 43PP295 rear-projection TV set (A10PTV chassis)
- Philips 29PT2152/79R TV set (L01.1 chassis)
- Philips 32PW4523/79R TV set (L2K3 chassis)
- Philips 32PW6516/79R TV set (A10E chassis)
- Philips 29PT6361/79R TV set (A10A chassis)
- Philips 32PW8806/79R TV set (MG2.1E chassis)
- Samsung CS-721APF TV set (SCT52A chassis)

Flat-panel TVs

Repairs to plasma and LCD TVs are becoming more and more a closed-shop affair, with only the manufacturers and their agents having access to service manuals, modifications and spare parts. As in other areas, it's the small independent operators that are losing out but that's economics.

It seems too that when it comes to flat-panel displays, it is increasingly becoming a case of either it works or it doesn't. If it is the latter, it's probably a display problem and the unit is beyond economic repair.

Of course, these displays are now selling like hot cakes, with reliability and quality rising exponentially and prices dropping. This works heavily against third-party repairers and long warranties further reinforce the in-house scenario. With these sets, repairs are only ever done at board level (like computers) which further shuts out the small operator – not that it's really practical to do anything else.

The other major loser is the environment in the form of landfill for old CRT TVs and monitors. However, there is one growth sector in our business and that is installing these new flat-panel systems, particularly when it comes to integrating them with older systems.

Until the advent of the HDMI interconnection system, connecting all the customer's accessories to the limited (and diverse) inputs available on their display could sometimes get rather hairy. In many instances, additional AV switching equipment has to be added to the installation to hook everything up. Of course, this can sometimes be rather confusing for the client who now has to become familiar with the new technology, as well as learning to drive it.

Another difficulty is that with the UHF band being choc-a-bloc, interference has become a problem with RF outputs from combos, etc. This means that you really need to have your wits about you when taking on an installation, plus lots of compatible cables and adapters.

Some clients have also yet to realise that when they purchase gear to add to their system, they are often creating unnecessary duplication. They really don't need two lots of VCRs or DVD players, so for everyone's sake, try to keep it simple!

CRT TV repairs

Repairs to CRT TVs are increasing in line with their complexity. In order to keep up with flat-panel sales, more and more sophisticated options are now being offered in CRT sets for less and less money. For example,

...MOST TV SETS ARE VARIANTS OF THE ORIGINAL "MOUSETRAP"

for just $700 or so, you can get you a large wide (16:9) flat screen with PIP (picture-in-picture), Teletext and all sorts of digital enhancements – often bundled with an extended warranty. The same set would have cost $5000 or more just five years ago.

Unfortunately, this technical wizardry often can not be fixed in the home and so the set has to be taken to the workshop for repair. And for that you need a large van and two strong blokes to lift and carry these large, heavy sets. The same goes for rear-projection sets, which are even bigger.

In many cases, the fault symptoms are intermittent which makes it difficult to estimate repair costs. Intermittent faults also mean long delays because of the soak testing required to confirm that the fault has indeed been found (and to reduce warranty claims).

Unfortunately, many clients get frustrated because of this and don't comprehend the complexity of these sets. They didn't pay much for it, therefore it has to be simple and it must be easy to diagnose, locate and replace the defective item – or at least, that's how they think.

In reality, the fault might not be

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IN MANY INSTANCES, ADDITIONAL AV SWITCHING EQUIPMENT HAS TO BE ADDED TO THE INSTALLATION TO HOOK EVERYTHING UP...

in the set itself. Instead, it could be due to its environment – dampness, humidity, heat, etc – or it could be due to customer ignorance and incorrect operation. If indeed it is the set that's at fault, it could be a hardware or software problem – or both.

Faulty Philips sets

Because we are a Philips agency, we naturally get to see a lot of them – Philips sets, that is. Let's take a look at a few common scenarios:

Case 1: a Philips 43PP295 A10PTV rear-projection TV will fire up with sound but there's no picture. However, when you use the remote to switch it to standby, the picture briefly appears for two seconds.

The fix for this is to realign control G2 on the focus block. One of the three adjustments is sitting on the edge of its range, causing blanking of the picture tubes which will even turn the set off.

Case 2: similar problems can occur with the Philips L01.1AA and its variant L2K3 chassis. In one case, a Philips 29PT2152/79R was hard to turn on and often switched itself off. When switched to the SAM mode (Serve Alignment Mode), it would occasionally display error 11, which is a "Black Current Loop Protection" error code normally associated with the CRT (flashover) or RGB amplifier (IC7330, TDA6107Q).

Well, I not only replaced the IC but also the whole board without result. I then tapped the CRT neck fairly violently but all to no avail. The problem again was the flyback transformer's G2 control being just on the cusp. Slight realignment fixed that problem.

Case 3: one 2004 32PW4523/79R TV came in with a blown line output transistor (Q7460, BU4508DX). I replaced this along with C2455 (47µF 25V) in its base circuit, as this has been known to cause this sort of failure. I also replaced C3465 (680pF 2kV) in the collector circuit.

That done, the set came on with perfect sound and picture and no error codes (originally they were 2 and 11 for horizontal protection). However, after a short period, the transistor started to get extremely hot and the picture width started to pulsate horizontally.

Thinking it may be due to the east-west FET (Q7400, FSTP3NGOFP), which is right next to line output transistor on the heatsink, I replaced that too but the fault remained. I then replaced the flyback transformer as well and then spent a lot of time on the power supply as V_{bat} was reading +143V instead of +140V. In particular, I changed C2526 (470µF) on pin 1 of the TEA1507 power supply controller (IC7520) but to no avail.

Eventually, I was put on the right path by a technician from Victor Electronics who suggested I look closely at the horizontal drive transistors (Q7461, Q7462 & Q7463). Q7461 and Q7463 are normal BC337-25 and BC327-25 transistors, while Q7462 is a surface-mount PDTC1432T device, so I decided to replace the two easy ones first.

When I removed Q7461 next to relay 1400, I noticed that the PC board beneath it was discoloured due to overheating. Replacing this transistor significantly reduced the temperature of the line output transistor.

However, as the set was under warranty and the owner was unhappy with the "quality of our service", we felt that a replacement chassis was the best form of insurance we could give.

By the way, it is really gratifying to find the level of cooperation between competing businesses these days, especially if you are a member of TETIA or TESA (Television and Electrical Technicians Institute of Australia and the Service Association). They have an excellent chat-room service for members called "CINLIST".

SSB board

The Philips A10 series of TV chassis continue to provide a steady source of income due to their SSB (Small Signal Board) and its microprocessors. However, it by no means certain that replacing the SSB module will fix the fault(s).

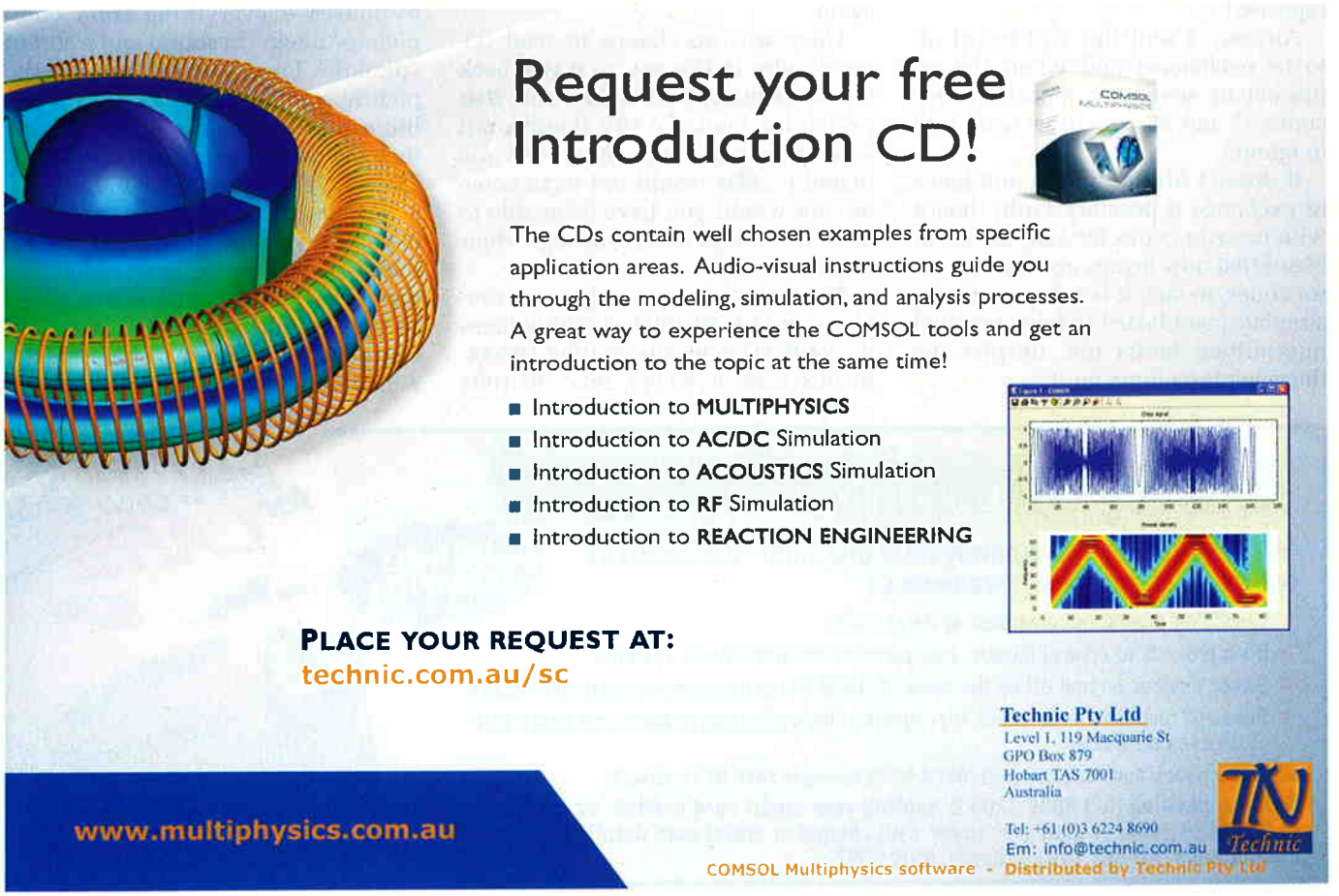
I was called out to a 32PW6516/79R using an A10E chassis. The complaint was that it had initially begun to intermittently vary the sound volume (either being too quiet or too soft) but now the set was dead.

When I arrived, I persevered longer than the client was prepared to and eventually managed get the set to come on. When it did, I quickly typed in "062596" and "i" to get into the SAM mode. Once in this menu, I could see how much the set had been used and what version software was installed (currently A10EP 1-1.6). More importantly, I could see it had an error 6 reported which I cleared, while all the option codes were correct.

Error code 6 indicates a general data bus fault on the I²C SDA and SCL lines. This can be caused by two surface-mounted zener diodes (6257 and 6258) near the tuner on the Large Signal Board (LSB).

Unfortunately, access to this part of the set is quite poor and the diodes in question are not shown on the PC board component layout (probably because they were only fitted in earlier models).

Removing these diodes really requires you to first remove the chassis, after which you remove the large signal board from the plastic frame. The board can then be turned upside down so that the diodes can be located and removed (without damaging the very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fine board tracks connected to them).

I did this and then left the set on soak test. However, just as I was about to declare that the fault had been fixed, the set turned itself off. I immediately switched it back on and checked the error codes to find none had been reported!

Anyway, I sent the SSB board off to be exchanged and when the replacement arrived it reported error codes 17 and 23 which we were told to ignore!

It doesn't fill you with confidence to exchange a possibly faulty board with no error codes for a replacement board that now brings up two new error codes. In fact, it is not unusual for a replacement board to have residual intermittent faults too, despite the thorough tests done on it.

If some of the power supply rails to the SSB are intermittently faulty and give high or low outputs when warm, these too can give erroneous error messages. In this instance (fortunately) the replacement SSB fixed the fault. I just(!) had to reset all the geometry and other preset controls (including check the option codes) for this model, which can take up to an hour or so to do.

I also had a Philips 29PT6361/79R A10AA chassis that worked fine except that changing to AV1 or AV2 turned the set off! The error codes varied but 2, 13, 16, 17 and 23 come up the most often. 17 & 23 can be ignored, 16 is a data line problem and 2 is a vertical problem. I resoldered the vertical output IC7501 and checked for the two zeners but the fault persevered and only a replacement SSB fixed the problem.

Old-fashioned servicing

A 2000 Philips 32PW8806/79R MG-2.1E chassis was dead except for the Standby LEDs which went from Red to Yellow to Green and then to Red again.

There was no chance to read the error codes in this set, so it was back to old-fashioned servicing and first principles. First, the +5V standby rail was obviously there otherwise the Standby LEDs would not have come on, nor would you have been able to hear the relays click through their sequence.

The relays are known to give trouble, especially RL1002 which switches the 240VAC to bridge rectifier D6514. In this case, however, relay RL1002 was OK as I had +330V right down to the switching FET (7540).

From there, it didn't take long to discover that there was nothing coming out of the secondary windings of chopper transformer TR5550. I checked for DC shorts but found none and the line output transistor (Q7421) also checked out.

The problem seemed to be that there was no drive to chopper transistor Q7540 from pin 3 of IC7520 (MC44603). This is a fairly complex control IC with a lot of in-built protection circuits.

I started by measuring the supply voltage (V_{cc}) on pin 1 of the IC with my DVM as I switched the set on, not expecting much. This supply voltage is derived from a separate winding on the chopper transformer (TR5550) and is rectified by diode D65625. It should be about +17V and I was surprised to find that not only was there voltage on pin 1 but the set then tried to come on with EHT and everything!

I did this several times with and without the meter, with a dummy load on the V_{bat} (+140V) line. I also tried switching the set on from Standby as well as from the full-off mode.

Well, did I get a set of mixed responses – everything from completely "no-go" to sound and a sort of "picture". I say "sort of" because the picture actually consisted of a white line across the screen, which indicated that the vertical output IC (IC7600, TDA8177) had probably failed.

Because of the lack of access I had to carefully remove the Large Signal Board and mount it on its side, then move the Small Signal Board (SSB) so that I could get at the circuit. Of course, with wires everywhere and the whole thing balancing on the edge of

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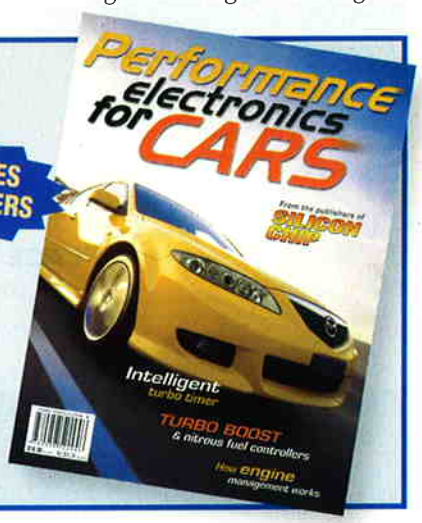

the bench, it was not an ideal situation for measuring high voltages on the hot side of the transformer.

In the end, I decided not to muck about and I just changed IC7520 and IC7600 – almost on a suck it and see basis. I then reassembled it but sorting out which plug goes to which socket took some time as they are all unmarked. Eventually, with it all back together, I switched on to find that the picture and sound had been restored.

I then entered the SAM (service alignment mode) by shorting pins 1 & 2 of connector 0356 on the SSB. This told me that there was an error on the +5V supply rail but gave no number as the Service Manual says. What's more, when I cleared the buffer, there were no more instances of any errors, regardless as to how the set was switched on and off (ie, to standby or full-off).

The set was thoroughly soak tested before being returned to its owner. However, I remain sceptical as to whether it's really permanently fixed or whether it has just decided to work again for the time being. Time will tell!

The fancy Samsung

I'd always thought Samsung catered for the lower price range but Mr Giorgio changed my perception when he brought in (thankfully) his 1996 52kg 72cm Samsung CS-721APF (SCT52A chassis) which was utterly dead.

I took the back off and immediately realised that I would also have to remove the horn-loaded bass reflex loudspeakers. I also noticed a number of modules with labels like Teletext, PIP and Twin Tuners, not to mention multi-system, so this was no cheap TV.

Access to the power supply deflection panel wasn't good but no worse than for other manufacturers. I removed the entire PC board and began checking it with an ohmmeter.

There was continuity all the way to relays RL801 and RL802, as well as to power bridge rectifier D805. It was this area I needed to investigate the most as power is required to switch on LEDs PD01 and PD02 and these two relays.

I didn't have a service manual for this particular set and in fact, it was the first one I had ever seen. However, from what I could work out, it needed at least 5V to operate the microprocessor, the driver transistors and the relays and this was supplied via D823 from pin 5 of T802.

I could see I had +330V going in and out of pins 1 and 2 of T802 but was it actually being fed to IC803? And then I spotted it – this 8-pin IC was not only black but the whole area around it was also black. Fairly obviously, there had been some pyrotechnics around the IC.

When I cleaned it all up, IC803 turned out to be a TOP210ES switchmode FET IC. And when it had failed, R804 (27Ω) had also sustained some friendly fire, as had C809 (47µF 25V) – although the wounds were only cosmetic. I replaced all three components plus the fuse and gingerly switched the set on. It worked like clockwork, much to my relief.

I have no idea why the IC failed. It may been caused by a power surge or a wandering insect but there were no other clues so it must remain a mystery! SC

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Vintage Radio

By RODNEY CHAMPNESS, VK3UG

The EILCO 6104 lunch-box RFDS radio

This view shows the set with the front cover removed, ready to be connected to a 12V battery, antenna and earth.

Radio transceivers designed for use with the Royal Flying Doctor Service (RFDS) are now scarce but well worth collecting. My EILCO RFDS radio transceiver is one recent acquisition that I've been able to fully restore.

THE AERIAL MEDICAL SERVICE (AMS) commenced operation in 1928 from Cloncurry in north-west Queensland, providing medical assistance to people in the outback. Before then, with no telephones or good roads in areas remote from Cloncurry, it was extremely difficult for people in those areas to access medical services – even though Cloncurry boasted a well-equipped hospital.

By contrast, the AMS had a doctor who could fly out to visit people in need of medical attention. Subsequently, the AMS became much more effective when, in 1929, the first radio link in what was to become the Royal Flying Doctor Service (RFDS) commenced at Cloncurry.

The radios in use at station homesteads at that time were extremely simple, consisting of a 1.5W single-valve Morse code transmitter (crystal controlled) and a 2-valve regenerative high-frequency (HF) TRF receiver. The base station was much more complex, as it transmitted voice with a power of 50W and used a high-performance receiver in order to receive the low-powered homestead transmissions (see "Outback Radio from Flynn to Satellites" by Rodney Champness for more details on the early days of the RFDS and the radios used in the outback).

The RFDS radios evolved over the years from sets made (initially) almost exclusively by Traeger Transceivers to those made by a number of other manufacturers. Traeger produced many fine transceivers over the years but their methods of construction and the designs used eventually became outdated.

Traeger had pioneered the use of plug-in modules for the transmitters and receivers. This technique worked

extremely well when only three channels were allocated for a particular flying doctor network. It meant that if people were transferred to another network or if a frequency change for a network was necessary, then all that had to be done was to send a plug-in module out to the affected stations. This module could be installed and correctly adjusted by relatively non-technical people.

Unfortunately, this approach subsequently became cumbersome and expensive when more than five channels were needed.

The birth of EILCO

One of the companies that rose to the challenge of producing transceivers suitable for use in the outback was the Electronics, Instrument and Lighting Company Pty Ltd (EILCO), which is known these days as Codan. EILCO was started by three University of Adelaide graduates – Ian Wall, Alistair Wood and Jim Bettison – in 1959. As a sideline, before the establishment of EILCO and before graduating, they often repaired equipment for the university and in some cases built better replacement equipment.

In 1961, they were asked to complete the construction of some HF radio equipment for the Anglican Bush Church Aid Society at Ceduna. They looked at the design and the partly constructed transceivers and decided that a different approach to the job would be better for all concerned. The idea was accepted and the EILCO 6104 transceiver was born.

The set itself is about the size of a lunch box. It has five crystal-locked transmit and receive frequencies and an 8W HF AM transmitter which covers a nominal frequency range from 2-7MHz.

The EILCO 6104 subsequently proved to be very popular as a portable transceiver with the RFDS networks, mineral exploration teams, government departments and many other groups that were just realising the value of communications in the outback. The set was easy to use – it was only necessary to pull up along the track, open the set up, put the battery clips onto the 12V vehicle battery, sling up a wire antenna into a tree (hopefully there was one nearby, even if stunted), attach an earth, adjust the tuning controls and call the base station.

In short, the design was a big success and Codan has since grown into a well-known and respected company in the field of HF radio communications equipment.

This above chassis view of the 6104 shows the unit with the power supply module (bottom) swung out of the way. It normally sits above the PC board.

The 6104

As mentioned earlier, the 6104 was initially designed for use with the Anglican Bush Church Aid Society. However, it's a sure bet that the founders of EILCO saw that the set would also be suitable for use by other organisations with only slight modifications to the basic transceiver.

By the way, the set was the fourth unit that EILCO designed in 1961, hence the 6104 type number. However, while the first two digits indicate the year of the design, they do not necessarily indicate the year of manufacture.

The set itself is built into a metal "lunch box" case measuring 295mm long (including protrusions), 210mm high (including handle) and 105mm wide. As shown in the photo, removing the lid reveals a very neat and uncluttered transceiver control panel.

The far left controls are used to tune and load the transmitter to the antenna in use, on any particular frequency selected. As an additional aid to tuning "unusual" antennas, a control marked 1-2-3 is also fitted.

The two terminals along the top of the control panel with the torch globe between them are the antenna and earth terminals. The torch globe is used as an indicator to show when the transmitter is correctly tuned – ie, when the globe is at its brightest.

Note that when the transmitter is correctly tuned to the antenna, the receiver is also tuned. That's because

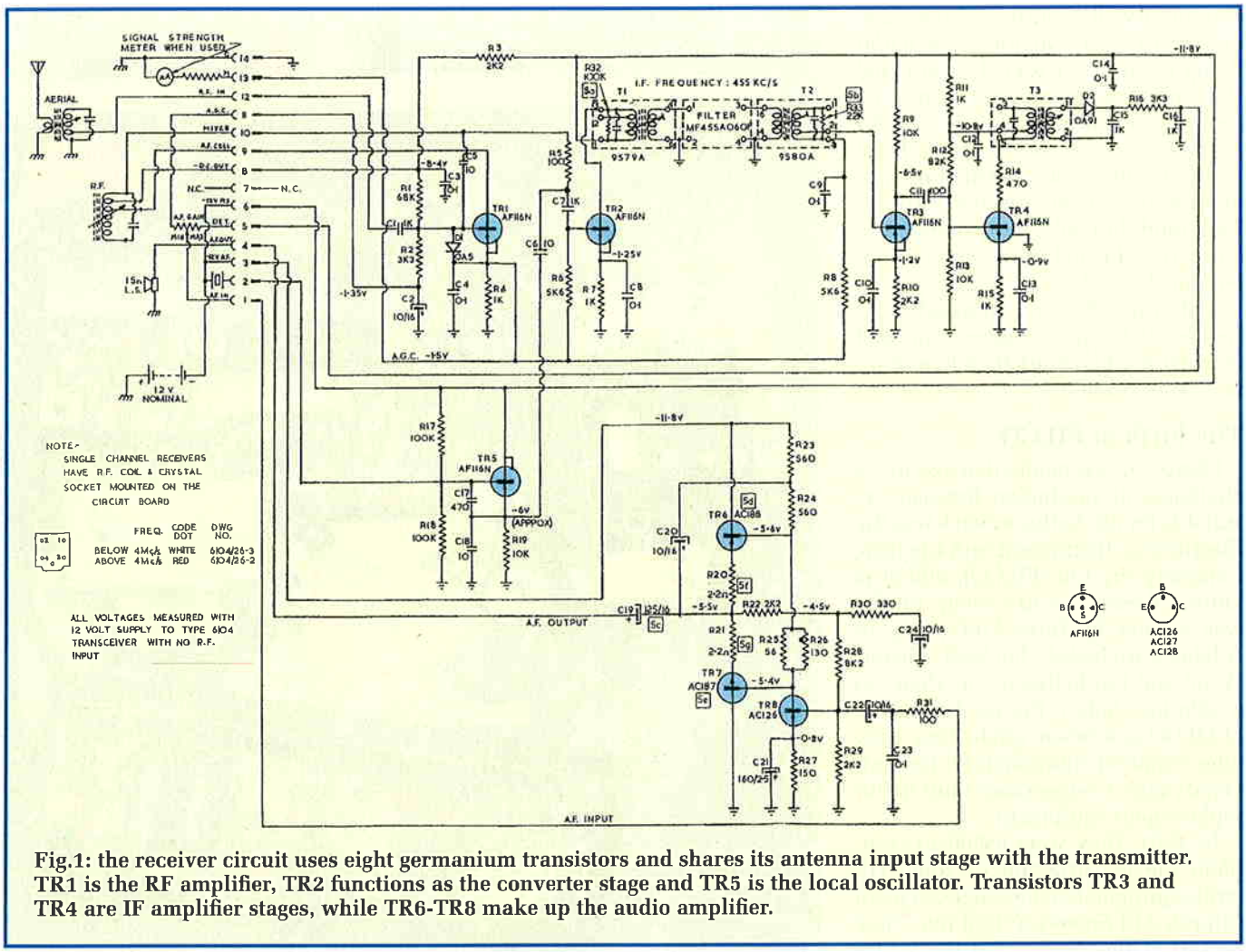


Fig.1: the receiver circuit uses eight germanium transistors and shares its antenna input stage with the transmitter. TR1 is the RF amplifier, TR2 functions as the converter stage and TR5 is the local oscillator. Transistors TR3 and TR4 are IF amplifier stages, while TR6-TR8 make up the audio amplifier.

the receiver uses both the loading/tuning circuitry and the transmitter output circuit as its input circuit. This is an advantage when the transmit and receive frequencies are the same or do not differ greatly. Conversely, if they do differ greatly, the receiver's sensitivity will be severely reduced.

The remaining control at the top of the panel is used to switch between transmit and receive. In the receive position, only the fully-transistorised receiver is operating and this draws around 25mA with no signal input. The set can therefore be used for monitoring for long periods without flattening the 12V battery (after all, who wants to have a flat battery in their vehicle)!

In the standby position, the transmitter's valve heaters are turned on (so that it is ready to operate) and the current drain rises to around 0.8A. And finally, in the transmit position, the transmitter is operating and the current drain rises to around 3A.

The remaining controls on the front panel are an on/off volume control (lower centre) and the channel-change knob (bottom, far right).

Receiver circuit

The 6104 was built in several variants, the two main ones being the Mk.1 and the Mk.2. The main differences between these two variants are in the receiver.

The unit I have is the Mk.2 with the 6415 receiver. This receiver is a plug-in unit and can either be used in the 6104 or used as a separate local or remote monitoring receiver with one or more channels. However, when remotely controlled, only one channel was commonly fitted.

In particular, the RFDS and many other HF services used the 6415 and similar units as remote receivers, locating them well away from sources of electrical noise, such as towns.

Fig.1 shows the circuit details for the receiver. As shown, it is an 8-transistor unit based on second-generation germanium transistors.

As stated previously, the antenna input circuit is shared with the transmitter. Following this stage in an RF amplifier based on TR1 and its input is protected from high-level transmitter signals – either from its own transmitter or another nearby transmitter – using an OA5 diode connected between base and emitter.

Transistor TR2 functions as a converter stage, while TR5 functions as the local oscillator. Note that the local oscillator is crystal controlled.

The following IF stage is based on transformers T1 and T2, with a ceramic filter between the two transformers. It operates at 455kHz and the IF input circuitry establishes the shape of the IF amplifier response curve.

Transistors TR3 and TR4 function as RC-coupled IF amplifier stages. These in turn drive transformer T3 and the detector/AGC diode (D2). The resulting AGC voltage is applied to the base

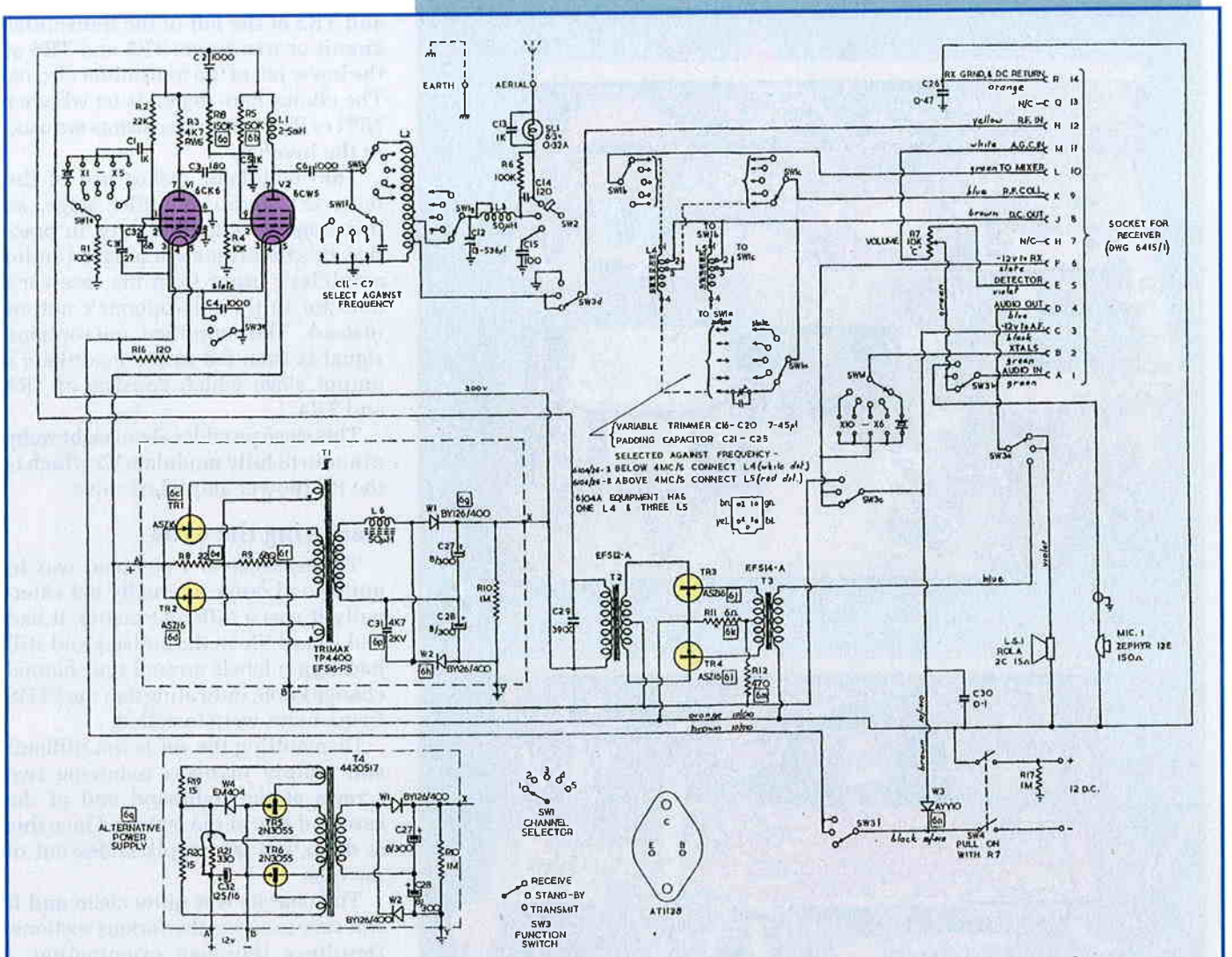


Fig.2: the transmitter circuit is a hybrid design, with valve V1 functioning as a Pierce oscillator and crystals X1-X5 setting the output frequency. V2 is the power amplifier output stage, while the modulator makes use of the receiver's audio amplifier stage to amplify the microphone signal. This signal is then fed to he modulator's output stage which is based on TR3 and TR4

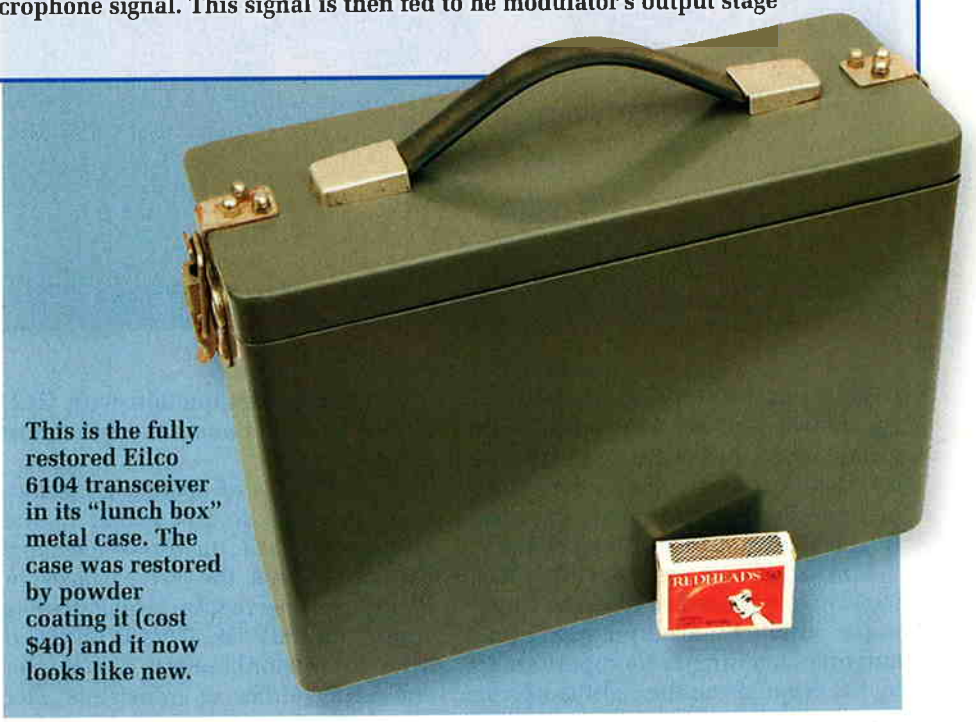
of TR1 which in turn controls the gain of transistors TR2 and TR3 in the RF and IF amplifier stages.

In addition, the audio signal from the detector is applied via a volume control to a 2-stage audio amplifier based on TR6-TR8. The output from this amplifier is fed to a 50mm loudspeaker on the front panel.

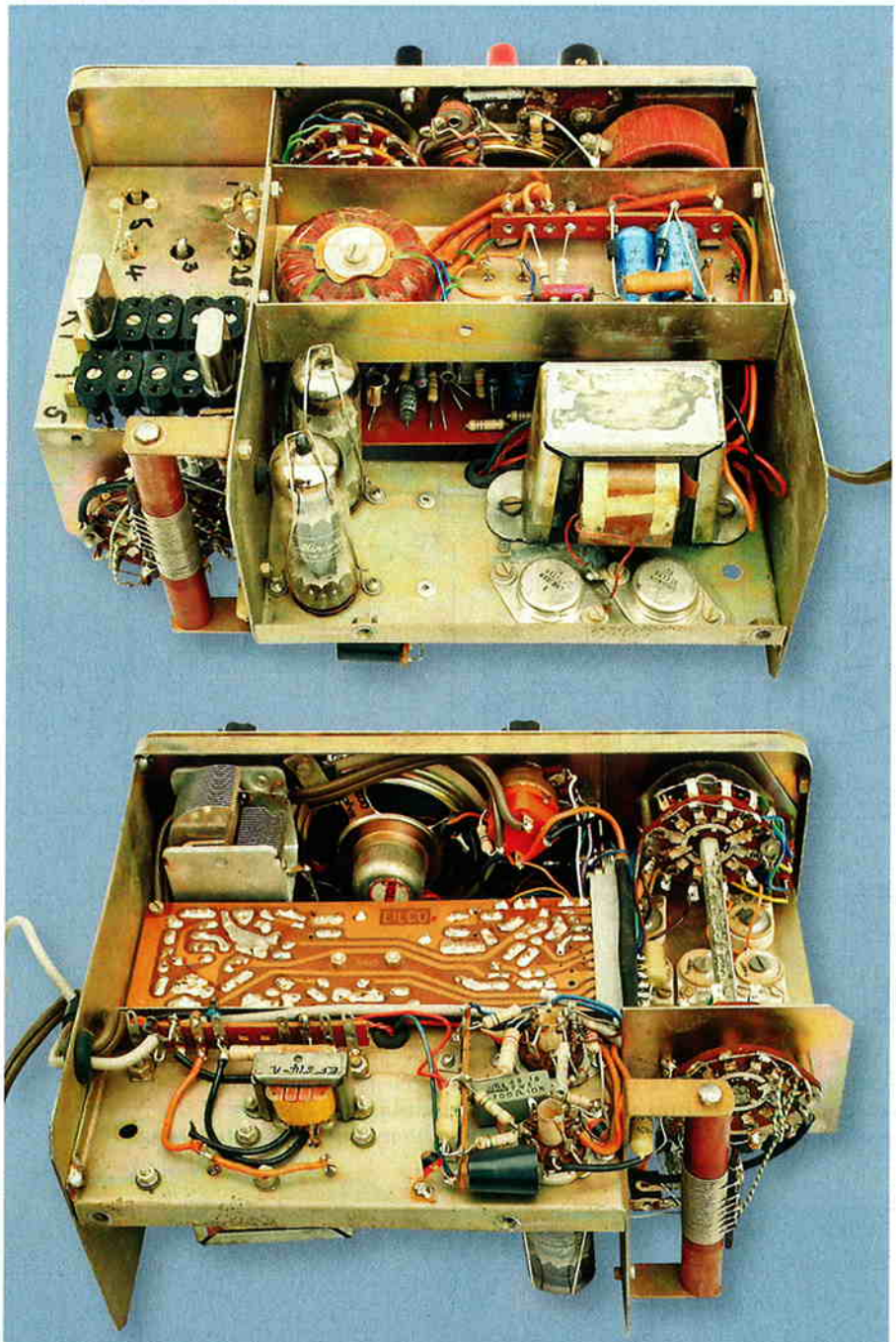
By the way, the symbol used for the transistors in Fig.1 may seem unusual, particularly for younger readers. In fact, it is one of the first symbols used for transistors and "Electronics Australia" magazine used it regularly in the 1960s.

Transmitter circuit

The RF section of the transmitter is



This is the fully restored Eilco 6104 transceiver in its "lunch box" metal case. The case was restored by powder coating it (cost $40) and it now looks like new.



These two photos show the top and bottom chassis views of the EILCO 6104 transceiver (taken from the rear). The two valves are used in the oscillator and power amplifier (PA) stages of the transmitter section (see Fig.2).

based on conventional valve circuitry. As shown, it uses a Pierce oscillator circuit based on a 6CK6, with crystals X1-X5 setting the frequency. This stage controls the grid of the power amplifier (PA) which is built around a 6CW5.

Coil L2 and its associated parallel capacitors are used to tune the transmitter output. Final output tuning and antenna matching is then performed by the tappings on the righthand side of coil L2 in conjunction with C12, L3 and the components connected to switch SW2.

A concise set of operating instructions is glued to the inside of the removable lid on the top of the carry case. Note that the valve stages in the transmitter require a high voltage supply of 300V DC. This is obtained from a transistor-based DC-DC inverter consisting either of transistors TR1 and TR2 at the left of the transmitter circuit or transistors TR5 and TR6 at the lower left of the transmitter circuit. The choice here depends on whether NPN or PNP power transistors are used in the inverter.

The modulator makes use of the receiver's audio amplifier stage, so this stage does double duty. In practice, this involves switching the audio amplifier's input from the receiver's detector to the microphone's output instead. The amplified microphone signal is then fed to the modulator's output stage which consists of TR3 and TR4.

This stage provides about eight watts of audio to fully modulate V2 which is the PA (power amplifier) valve.

Restoring the 6104

The transceiver I obtained was in quite good order internally but externally it was a different matter. It had had a hard life in the outback and still had Dymo labels around the channel change knob, indicating that the RFDS frequencies were installed.

Dismantling the set is not difficult and simply involves removing two screws at the righthand end of the case and two at the bottom. Once this is done, the set simply slides out of the case.

The chassis was quite clean and it was easy to access the various sections. Despite a thorough examination, I found no problems with the circuit and it's nice to have a restoration project once in a while that requires relatively little work.

I decided to tune the set up on 3565kHz, as I had crystals that suited that frequency which I had removed from another transceiver. Initially, I installed a 4020kHz crystal into the channel 1 position of the receiver (4000kHz - 455kHz gives a receive frequency of 3565kHz). That done, I was able to tune up the receiver by selecting various coil tappings and adjusting the trimmer capacitors for optimum performance.

The antenna coil can only be finally tuned when the transmitter is aligned. The IF was OK as the ceramic filter is a fixed-frequency device and won't shift frequency unless it is faulty. Transformers T1-T3 were also checked for alignment and were quite OK.

The transmitter was a little more difficult to tune up, mainly because I didn't have the alignment instructions.

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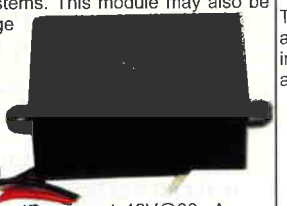

NEGATIVE ION GENERATOR MODULE. Same specs. as the unit above with differing case dim. Overall dim. of the main body are 37x17x17mm & the mounting holes are 67mm apart. **(IONB)** $12

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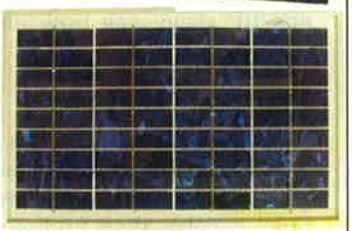

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SC_MAR_07

However, after working on many fixed tuned transmitters and receivers over the years, a reasonable "guestimation" of suitable taps and capacitor values can be arrived at.

Of course, only people with an appropriate transmitting licence should have a working transmitter. I experimented with the tappings on L2 and the values of the parallel capacitor as selected by switches SW1f and SW1g. In this case, getting the right tapping and capacitor value is a bit like experimenting with the tappings on a crystal radio to get best performance.

Eventually, I got it operating as it should, which meant that the receiver's RF stage was now also aligned correctly.

Repairing the case

As indicated earlier, the metal case was rather the worse for wear. In the end, I figured that there were others far more capable than I when it came to fixing the scratches and abrasions.

As a result, I removed most of the handles and clips, although I couldn't remove the clips at the end of the case. That done, I took the case to a local powder coating firm and they did a first class job on it – so much so that it now looks like new. At $40, it was a job well done.

The control panel was in reasonable order but I did have to remove the old Dymo labels. Unfortunately, glue had been used around the labels and this proved to be so difficult to remove without damaging the front panel that I just cleaned it as best I could.

Summary

The EILCO 6104 was one of the first truly "lunch box" size portable HF transceivers used in the outback. The outback of Australia has been a harsh testing ground for any equipment and the 6104 (and most other Australian-designed radio equipment) stood the test of time out there.

My unit works well but unfortunately it can not be used today on the amateur radio bands, as it is restricted to only five frequencies and to AM-only transmissions. By today's standards, it is well and truly obsolete.

That said, my 6104 is a worthwhile addition to my small collection of RFDS radios, dating from 1948 onwards. Early RFDS radios are scarce but some of the later ones are still available occasionally. They are well worth collecting, as they form part of our unique radio heritage. SC

Photo Gallery: AWA R39 Battery Receiver

MANUFACTURED BY AWA in 1937, the R39 is a 4-valve battery-powered receiver requiring 120V HT, 2V for the valve filaments and bias voltages of -1.5V and -4.5V. The filament and bias voltages were all obtained from an internally fitted, tapped, battery.

The valve line-up was as follows: 1C6 frequency changer; 1C4 IF amplifier; 1K6 reflexed 2nd IF amplifier/1st audio amplifier/detector/AVC rectifier; and 1D4 audio output. Photo: Historical Radio Society of Australia, Inc.

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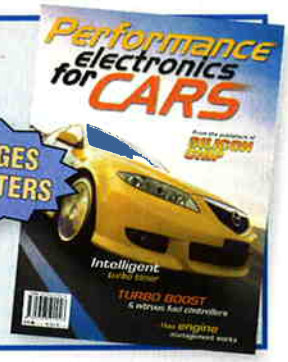

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Query on universal preamplifier

I built the Universal Preamplifier (SILICON CHIP, April 1994) as a phono preamplifier. I noticed that the inductors in the similar circuit published in the August 2006 issue had the wire passing through the inductor only once instead of four times as in the universal kit. Is one turn passing through the inductor a possible modification?

Also I noticed that instead of two 100kΩ resistors in parallel in the input stage, one 47kΩ resistor was used in the latter circuit. Can this modification improve the universal preamp? (C. A., Innisfail, Qld).

● One turn through the inductor core is correct, as is the 47kΩ resistor. Two 100kΩ resistors in parallel equal 50kΩ so there would be no point in changing to one 47kΩ resistor.

2N4992 for soft-start lamp circuit

With reference to the soft-start lamp circuit from the June 1986 issue of "Electronics Australia" (See Ask SILICON CHIP, November 2006, page 104), I successfully built quite a few of those back in 1986 to use with the expensive Philips "head-mirror" lamps which were very prone to failure on our 245-252VAC mains supply.

I still have some new 2N4992 SBS devices left in my stock. I would be happy to sell the devices for $5 each. A postal note with a stamped self-addressed envelope, maximum two devices per customer, would do the trick. (David Humrich, PO Box 117, Greenwood, WA 6924).

Query on AV signal generator

Do you have an error in the "Pocket AV Test Signal Generator", in the June 2006 edition? Both the schematic and the component overlay show pin 15 (V_{sync}) of IC2 (AD724JR) going to ground (logic low).

While researching the AD724JR for a project I am working on, I came across the following in Analog Devices data sheets for this IC. The "Pin Function Description" page states: 15 – VSYNC – Vertical Sync Signal (if using external CSYNC set at >+2V). The "Theory Of Operation" section confirms this: "If the user produces a true composite sync signal, it can be input to the HSYNC pin while the VSYNC pin is held high".

Thanks for a terrific magazine! The mix of projects, feature articles and special columns makes every month's issue a great read. I especially like "Serviceman's Log" and the cartoons that go with it add a few extra chuckles! (L. H., Lavington, Vic).

● The composite synchronisation signal generated by the firmware in the 16F84A-20 is inverted. As the sync input to the AD724 is simply an XNOR gate, grounding the VSYNC pin inverts the sync back to the correct polarity. The >+2V simply refers to logic high.

Alternatively, the HSYNC pin could have been grounded and inverted sync fed into the VSYNC pin. Another solution would be to tie HSYNC high and feed non-inverted sync into the VSYNC pin.

This feature of the AD724 makes it very flexible in terms of firmware development and PC board layout. Note, however, that by using separate H and V sync signals, you will not produce a

How To Reverse An AC Motor

Is it feasible to reverse/forward the motor rotation in an AC electric motor, through the use of a controlling switch? I wish to change the direction of rotation for relatively short periods of time at say, 3-minute intervals. (D. M., Binningup, WA).

● To reverse the direction of a single-phase AC brush motor, you need access to the field windings so that they can be reversed with an AC contactor with DPDT contacts. However, on many motors, getting this access is not easy. This applies particularly to universal AC (ie, series wound) since the field winding is split, on either side of the brushes. Shunt-wound motors are easier but are not very common these days.

To reverse a single-phase AC induction motor, you need to reverse the connections to the start winding, again using an AC contactor with DPDT contacts. Finally, to reverse the direction of a 3-phase induction motor, you need to swap the connections to one of the phase windings.

You really need to be very familiar with AC motors before you start accessing the connections underneath their terminal covers. If you get the connections wrong, you can easily burn out the motor. The same comment applies to the wiring of AC contactors – get it wrong and you could have a very hazardous situation on your hands.

Also, while considering the repeated reversing of any motor, you need to consider whether it should be stopped before reversing direction, as the surge currents will be very much higher if you simply slam it into reverse. Also, you need to consider whether the motor is rated for repeated starting, as its windings will run much hotter with the repeated surge currents.

true composite sync as per the Australian standards. This is why the signal is generated in firmware.

Quiz game circuit wanted

I wish to construct an arrangement similar to the one featured in the TV game "Spics and Specs". When the first contestant presses the button, it activates a buzzer or speaker and de-activates the rest. Has there been a similar project in SILICON CHIP or could you suggest a circuit that would operate in this manner? (D. B., via email).

● Our Quizmaster project published in July 1993 is your answer. This can cope with up to four players.

Noise-cancelling for bedrooms

I suggest a noise-cancelling project to cover the area at the head of a bed, even just the area of a pillow. I know how effective noise-cancelling headphones are (especially my Bose QuietComfort 2 set).

Of course, the difficulties increase with the volume covered but I understand some bizjets and luxury cars are fitted with noise-cancelling systems. With growing levels of urban noise at night, I suspect this would be a popular project. (R. H., via email).

● Thanks for the suggestion. However, you may not realise that you can make a big reduction in perceived noise, especially at low frequencies, merely by pulling your bed away from the wall by about 30cm or so. That may not be convenient but if it is possible, it might help at times when noise is a real problem.

Tiny PC power supply wanted

I want to fit a micro ATX motherboard into a custom enclosure. I have seen some cool enclosures in magazines where people have put PCs into everyday household appliances like toasters or wooden enclosures, etc.

The problem I have is that the enclosure I want to use won't fit a conventional PC power supply. I can fit a micro ATX motherboard, hard drive and a graphics card and a couple of fans but that is about it. I am looking to use an external plug pack to provide the power.

USB Electrocardiograph Has No Pulse

I built the USB Electrocardiograph (SILICON CHIP, February 2005) from a Dick Smith Electronics kit. The kit instructions state that the PIC is pre-programmed. I loaded the drivers and the software from the SILICON CHIP website and installed them as per the instructions.

I am using Windows XP Professional with SP2. I could not make the kit work and I loaded the drivers and software onto a portable PC with the same result. I checked the voltages in the analog and digital sections and all seem to be as expected. A scope on pin 7 of IC2b shows a fluctuation when either the CON1 or CON2 leads are touched. A ragged pulse is noted when the scope lead is connected to pin 3 of IC3.

LEDs1 & 2 do not flash when the PC software is communicating with the device. Any help will be greatly appreciated. (R. G., Stirling, WA).

● From your email it sounds as if either the VB6 ECG Program or the FTDI USB serial port driver have not installed properly or are not communicating with each other.

Have you tried checking the status of the USB driver, by going into Control Panel, then System and Device manager? You should be able to do this and find the driver listed under Ports – COM and LPT. When you check its Properties, you should see that it's installed OK and has the correct bit rate and COM port number 5. If not, you should be able to set them correctly. The VB6 program should also be set to the same COM port number and bit rate.

However, a plugpack typically provides a single voltage and to provide the various voltages to a standard ATX motherboard connector I need to add a small circuit board inside the case to take the plugpack input and produce the various voltages for the ATX connector, drive connectors, etc.

I have built a few kits so I have some idea of what is required to do this. However, if I design something myself, I may not quite get it right and may end up with unnecessarily large power dissipation (heat) happening on the board inside the case. Can you suggest a suitable circuit? (G. F., via email).

● It is not practical to try to design a switchmode PC power supply smaller than the ones you can presently buy off the shelf. They are very efficient, cheap and very compact for the large amount of power that they provide. Plugpacks simply do not have anywhere near enough power output to do the job.

ATX power supply plugs

Recently my computer died and I traced the fault to the power supply and in particular the 20-pin ATX plug (really a socket) that plugs into the motherboard. This plug is made of polyamide and is manufactured by Molex.

Despite my best endeavours, I was unable to get a replacement. Retail electronics stores stock other types but not this one.

It seems that the only solution is to replace the power supply and as I picked one up for $NZ30 it wasn't a huge problem. However, it irritates me that there may be many perfectly good computer power supplies that have become redundant for want of a plug replacement. (J. R., via email).

● We don't think there is any easy answer apart from perhaps picking up the odd computer from council clean-ups so that you have an array of connectors handy.

Loudspeaker selector wanted

I'm thinking of building a simple infrared-controlled speaker selector box to send music to various rooms in our house. I don't need to drive more than one pair of speakers at a time, so it'll ensure that the currently connected speakers are disconnected before connecting the new pair when a switch occurs.

I'm guessing the easiest way to build this would be with a PIXAXE and a set of relays. However, I'm not sure what

Adjustable Power Supply For Audio Amplifiers

I would like to suggest that SILICON CHIP designs a regulated split-rail power supply for audio amplifiers. The design should have an adjustable voltage range of up to ±37V at 3A as a minimum. I suppose it would be easiest to base the design on existing programmable voltage regulators such as the LM317, with one or two additional pass transistors for the extra current.

It could be designed to a format similar to the audio amplifier modules, so that the regulator and pass transistors can be easily mounted on large heatsinks if required.

There are many audio amplifier designs which I would imagine could benefit from the addition of a quality regulated supply, especially amplifier modules with a high continuous current draw (such as Class-A designs). The design should suit amplifiers in the small to mid-power range (say up to 60W) and perhaps could allow for a variable number of pass transistors to allow the current capacity to scale with the intended use. (P. T., via email).

● We have already designed a dual-rail fully regulated supply for amplifiers, in the August 1998 issue. It was used to power the 15W Class-A stereo amplifier.

As published, it delivered ±20V but it could be made adjustable, depending on the transformer input voltage. However, we do not regard such a power supply as being a big advantage for most class-B amplifier designs. For a start, most class-B designs already have quite adequate PSRR (power supply rejection ratio) and therefore there is no advantage in terms of residual hum and noise from the amplifier itself.

In fact, there is a disadvantage in terms of power output. Any normal class-B amplifier will have considerably higher music power output than its continuous power output (the ratio is referred to as "dynamic headroom") if it is used with an unregulated power supply. That is why all commercial amplifiers do not have regulated supplies.

Making the supply adjustable to cover a range of output voltages also presents a difficulty because if the supply is to have a big difference between its input and output DC voltages, it will need big heatsinks to dissipate the waste heat.

current rating I'll need for the relays. The speakers I'll be driving are fairly small (40W handling if I remember correctly). (J. B., Umina, NSW).

● We described a 10-Channel Infrared Remote Control Receiver in the February 2002 edition that could be modified to suit your purpose. As described, it is not a "1-of-10 selector" but rather it allows any output to be toggled individually. If you are familiar with PIC programming it should be easy to modify the existing code to perform the 1-of-10 function.

For 40W into 8-ohm speakers, relays rated at 3A or higher should be sufficient.

Project for hydroponic measurements

I built your "Digital Instrument Display For Cars" as described in the August 2003 issue but find I have no use for it any more. Is there a way I can use it in my hydroponic set-up? I need a permanent TDS or EC measurement and display. (T. L., via email).

● Unfortunately, this unit is not directly adaptable to the measurement of EC (electrical conductivity) or TDS (total dissolved solids). Both of these measurements of conductivity are made in milliSiemens/cm or micro-Siemens/cm and essentially require a high-impedance voltmeter circuit.

The Digital Instrument Display for Cars does not have a high input impedance although the input op amp (IC2a) could be adapted to provide this. However, to produce a reading of electrical conductivity, you also need a special probe and the instrument would need to be calibrated with a standard solution.

In short, the Digital Instrument Display could be adapted to an electrical conductivity meter but then only with a re-design of the input stages and rewriting the software code.

Source for high-temp epoxy resin

In your January 2006 article on the construction of the High Energy Ignition system, when detailing assembly of the Hall effect chopper to the rotor arm, you suggested the use of an epoxy resin made by JB Weld. Despite two emails to the company in the USA asking for a retailer here in the west I have received no response – not unusual for large US companies.

Could you therefore please let me have the name of the retailer you were able to obtain this product from – even if you are unaware of one here in Perth? (P. M., via email).

● We found JB Weld for sale in the hardware section of Kmart. It is best to get the standard version (part 8270) rather than the fast setting one because of its 315°C rating.

Measuring the speed of model planes

Is it possible to increase the range of the Radar Speed Gun (SILICON CHIP, November 2006) to 350km/h to measure the speed of model planes and cars. The speed gun would need to be pointing at the model at a tangent to the circular path of the model. Is there a size limitation with the model and how close would the gun need to be to the model? (C. H., Baulkham Hills, NSW).

● It is not hard to extend the speed measurement range of the Radar Speed Gun to over 350km/h. The main modification needed is to reduce the value of the capacitor between pins 3 and 5 of IC2 from its present value of 3.3nF to say, 2.2nF or 1.5nF.

However, it's hard to say if the project would be capable of measuring the speed of model planes or cars. The main limitation is likely to be the relatively small amount of metal in typical models which will result in only a very small amount of reflected microwave energy or "echo". The output of the Radar Speed Gun is quite small and the coffee-can antenna produces a transmit/receive beam pattern which is fairly narrow but possibly

not narrow enough to concentrate it sufficiently to get good results with small models.

It's possible that the beam could be better focused by adding a third coffee can to the front of the barrel but there is no guarantee that this would be sufficiently effective.

Priority switching for CB radio

I am trying to mix CB radio and mobile phone signals into my existing car speakers. The radio is a complicated affair that interfaces to steering wheel paddles, so there is probably no reasonable commercially available head unit that would help. It has no AUX input.

I am looking for a small mixer that I can cut into the front speaker cables and add the CB output to it. You can't just splice the cables because the radio/CD head unit would probably blow the CB unit. I can turn the radio off or down when playing with the CB but I don't want to have to switch the speakers. Hope you can help. (T. D., via email).

● Presumably you don't really want to mix the CB speaker and car radio signals. Instead, you really want the CB to have priority over the car radio when the CB is in use.

Assuming this is correct, you could achieve this "priority" function quite easily by modifying the VOX circuit we featured in the September 1994 issue. This monitored the signal from an electret microphone and it closed a relay whenever the microphone produced a signal above a certain threshold.

You could adapt it by substituting a 10kΩ resistor for the microphone and then coupling the signal from your CB via a 1kΩ resistor into the 0.1µF capacitor feeding diodes D1 & D2. Make sure you disconnect the 0.1µF capacitor from pin 1 of IC1a. You will need a DPDT (2-pole change-over) relay to do the speaker switching.

Ceiling fan timer query

Is there a way to use the Ceiling Fan Timer (SILICON CHIP, October 2005) with a light as well, as my toilet has the fan and light on the same switch circuit. (W. B., Toowoomba, Qld).

● Simply wire the fan and light in parallel.

Multiple Inputs For Remote Control Extender

I am building the Infrared Remote Control Extender (SILICON CHIP, October 2006) but will have multiple rooms where I want to be able to control my Foxtel box. Can I use one extender unit as the receiver and locate a number of TSOP4136s around the house on the ends of long cables or do I need a complete receiver unit for each room and drive the single IR LED? I can do without the confirmation LED.

Would there need to be any filtering into the IC2a/b inputs if a single receiver was possible and multiple long input lines were connected? Would the 5V circuit need to be changed to increase the current flow to multiple sensors? I'm looking at setting up about six rooms with sensors controlling a single Foxtel box. (D. C., Park Orchards, Vic).

● The circuit was designed for a single TSOP4136 but you could parallel up to three of these on the one receiver PC board. The 5V supply would need boosting by changing the 150Ω 0.5W resistor to 75Ω 5W.

We would not expect that you would need to filter the pin 1 outputs. These are open collector with a pull-up resistor and so paralleling is possible and the output impedance is low enough not to produce signal on its own due to interference.

Note that each TSOP4136 requires a 100µF bypass capacitor between pins 2 & 3.

Notes & Errata

Simple Variable Boost Control, February 2007: the text describing the wire colours on page 37& 38 is wrong. The wire from the ECU should be green and the wire to the boost solenoid should be blue, to agree with the diagram of Fig.3.

Fuel Cut Defeater For Cars, February 2007: on page 39, the text states "Check that the voltage at pin 8 of IC1 is +5.6V". In fact, the voltage is +12V, with respect to pin 4.

WARNING!

SILICON CHIP magazine regularly describes projects which employ a mains power supply or produce high voltage. All such projects should be considered dangerous or even lethal if not used safely.

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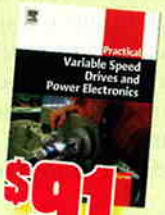

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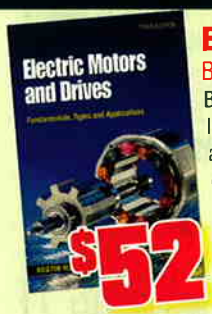

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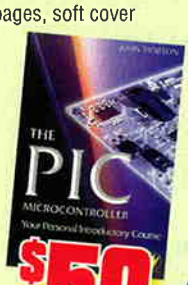

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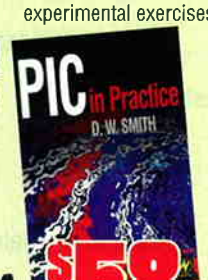

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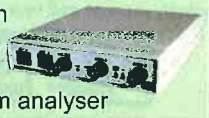

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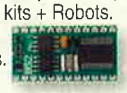

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